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Using kill-chain analysis to develop surface ship CONOPS to defend against anti-ship cruise missiles

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THESIS

USING KILL-CHAIN ANALYSIS TO DEVELOP SURFACE SHIP CONOPS TO DEFEND AGAINST ANTI-SHIP CRUISE MISSILES

by

Roy M. Smith

June 2010

Thesis Advisor:	J. M. Green
Second Reader:	D. A. Hart

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USING KILL-CHAIN ANALYSIS TO DEVELOP SURFACE SHIP CONOPS TO DEFEND AGAINST ANTI-SHIP CRUISE MISSILES

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Submitted in partial fulfillment of the
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The premise of this thesis is that a kill chain analysis can be used to ascertain survivability probabilities that can be used to analyze ship vulnerabilities to the anti-ship cruise missile (ASCM) problem. Using the kill chain framework, two approaches are examined. The kill chain, as perceived by the eyes and sensors of the ASCM, are used for the analysis. From this perspective, the ASCM encounters the formidable layered defense of a target ship to include hard kill and soft kill measures. The first analysis uses a time line framework to calculate potential engagements and from this, compute the likely probability of success. The second approach uses decision tree software to analyze a single ASCM vs. target ship surface to air missile encounter using a Monte Carlo simulation with derived probabilities of success and failure. This paper looks at eighteen ASCMs available in the world today and examines their probability of success against a generic ship that has a defensive suite similar to the current Arleigh Burke class destroyers. A key finding was that for ASCMs to be successful, they should fly lower and faster and incorporate soft kill measures. Hence, future ship builders need to be prepared to counter more sophisticated threats when designing warships.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
ASCM	Anti-Ship Cruise Missile
CIWS	Close-In Weapon System
CNR	Carrier to Noise Ration
ECM	Electronic Countermeasures
EO	Electro-Optical
ESSM	Evolved Sea Sparrow Missile
GPS	Global Positioning System
HK	Hard Kill
IR	Infra-Red
km	kilometer
LRSAM	Long Range Surface to Air Missile
m	meter
OTH	Over the Horizon
PD of P_D	Probability of Detection
PKH or $P_{K/H}$	Probability of Kill given that a Hit occurred
PS or P_S	Probability of Survivability
RCS	Radar Cross Section
RF	Radio Frequency
SAM	Surface to Air Missile
Sec	second
SK	Soft kill

Acronym	Definition
SM	Standard Missile
SNR	Signal to Noise Ratio
SRSAM	Short Range Surface to Air Missile
STDEV	Standard Deviation
UV	Ultra Violet

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I. INTRODUCTION

A. BACKGROUND

Much discussion has occurred in recent years concerning the proliferation of cruise missiles throughout the world (Burgess 2008). This proliferation raises concerns for the U.S. Navy because, in recent times, the Navy has operated more in littoral regions rather than in the open seas. The littoral regions create vulnerabilities to Navy ships that are absent in the open seas. Placing Navy ships in this region makes them vulnerable to a wide range of threat systems that many countries/groups can now afford to own and operate. Although some of these threat systems date back to the U.S.-Soviet cold war days, many can easily be modified with newer electronics and quality GPS navigation (Burgess 2008). These modifications can improve tracking and controlling algorithms due to significant advances in these technical arenas. It is all too easy to purchase these weapons on the open market. Burgess' article suggests that some missiles can be purchased for as little as $64K (US Dollar). Mahnken (2005) says that cheap anti-ship cruise missiles (ASCMs) can be purchased for $100K and that the cost has decreased significantly in recent years. This makes ASCMs available to a wide variety of countries and non-state actors—both friendly and non-friendly.

The ASCM problem is not likely to go away any time soon. Therefore, ships built for the twenty first century must be designed to deal with them in order to survive. This paper takes a look at analyzing this problem using a kill-chain analysis with the assistance of decision tree software.

B. PURPOSE

The purpose of this thesis is to investigate the potential to defend against anti-ship cruise missile threats to Navy ships using decision analysis techniques and within a kill chain framework. Many studies of ASCM's use computer modeling that requires extensive computer resources. The proposed technique in this thesis uses commercial off-the-shelf (COTS) software programs and can be computed on a standard issue

computer capable of running enterprise-approved spreadsheet software. The flexibility of this approach to the problem, lends itself to easy modifications and tailoring to answer similar questions for other threats and other targets.

C. RESEARCH QUESTIONS

What can ship designer's do to improve survivability against anti-ship cruise missiles? What ASCM features can be exploited to enhance the ability to attack them before they reach their target? How can common software tools such as decision tree models and spreadsheets be used to help analyze this scenario?

D. BENEFITS OF STUDY

This study intends to help ship designers better understand the cruise missile threat from the perspective of the anti-ship cruise missile using simple, off-the-shelf, and readily available software tools. This knowledge can provide ship designers additional tools to attack the ASCM problem and incorporate features in their designs to enhance ship survivability.

E. SCOPE AND METHODOLOGY

This thesis starts with the kill chain as outlined in *The Fundamentals of Aircraft Combat Survivability Analysis and Design* (Ball 2003), and then modifies it to address ASCM. The Ball 2003 text is a textbook for aircraft survivability, but the similarities between missiles and aircraft can be exploited to solve a similar problem for cruise missiles. Only minor modifications to address ASCM survivability are needed. In most cases, aircraft survivability factors can be directly applied to ASCMs. Differences include size, weight, performance characteristics, and the fact that missiles do not carry humans.

For the purpose of this study, only open source unclassified data is used. A typical ship in the U.S. Navy is an Arleigh Burke class destroyer. Its weapon system defense suite is described in Table 1. The application is not limited to any one class of ship; it can be applied to any ship. Further analysis on specific ships can always be accomplished.

Characteristic / Ship Weapon	Function	Max Range	Min Range	Guidance or Band	Navigation	Terminal Homing	Speed (Mach)
Surface-to-Air Missiles (SAM)							
- SM-2 Blk III/IVA	Long Range	167 km 90 nmi	74 km 40 nmi	Command	Inertial	Semi-active RF/IR	M 3.0
- RIM-162 ESSM	Short Range	18.5 km 10 nmi	1.5 km .8 nmi	Semi-Active	Inertial	Semi-active RF/IR	M 3.5
Guns							
- Vulcan Phalanx	Point Defense	1.5 km .8 nmi	-	Command	N/A	N/A	1,030 m/s
Radars							
- SPY-1D	Air Search/Target Acq	167 km 90 nmi	-	E/F	N/A	N/A	N/A
- SPS-64/SPS-67	Navigation	25 km 13.5 nmi	-	I/J	N/A	N/A	N/A
Electronic Warfare							
- SLQ-32	ESM/ECM	-	-	N/A	N/A	N/A	N/A
- Super RBOC	Chaff/Flares	-	-	N/A	N/A	N/A	N/A
- Nulka	Chaff/Flares	-	-	N/A	N/A	N/A	N/A

Information extracted from Jane's Strategic Weapon System's at www.janes.com July 24, 2009

Table 1. Typical Arleigh Burke class ship characteristics.

For the ASCM kill chain analysis, the probability definitions of Table 2 are used. These definitions are based on the Ball (2003) definitions, but are modified for application in the ASCM case. An ASCM will closely mirror an aircraft with the exception of physical characteristics that will change probabilities in the kill chain. The term “propagator” in this case refers to a defensive item from the target ship. For an *Arleigh Burke* class destroyer, as shown in Table 1, the propagators would be an RIM-66 Standard Missile 2, Medium Range (SM-2MR), a RIM-162 Extended Sea Sparrow Missile (ESSM), or bullets from the Vulcan Phalanx Close-In Weapon System (CIWS). Additional factors affecting the kill chain are the soft-kill measures such as electronic jamming, use of decoys (both Radio Frequency (RF) and Infrared (IR)), and the use of expendables such as chaff/flares. For a real life example, an *Arleigh Burke* class destroyer has a SLQ-32 jamming suite and SRBOC chaff launchers and Nulka off-board RF jammer decoys (FAS.org - DDG-51 *Arleigh Burke*-class).

SUSCEPTIBILITY DEFINITIONS (Ball 2003)

P_A = Probability threat weapon is active, searching and ready to encounter the ASCM that entered its defended area. Weapons with respect to the ASCM include the SAMs, guns, jamming, chaff, and decoys.

$P_{D|A}$ = Conditional probability that the ASCM is detected, given that the threat is active

$P_{L|D}$ = Conditional probability that the ASCM is tracked and engaged, a fire control solution is obtained, and a missile is launched or a gun is fired at the ASCM, given that the threat was active and detected the ASCM

$P_{I|L}$ = Conditional probability that the threat propagator (target ship system) intercepts the ASCM, given that the propagator was launched/ fired at the ASCM and engaged in a fire control solution

$P_{H|I}$ = Conditional probability that the propagator (target ship system) hits the ASCM, given that the propagator has intercepted the ASCM

Ship perspective probabilities (Ball and Calvano 1994)

P_{DCT}= Probability that the propagator (target ship system) will detect the incoming ASCM, classify it as a threat and produce a targeting solution given that the target ship is active and ready to deploy its defensive weapon systems. This is similar to $P_{D|A}$ times $P_{L/D}$ above and will be depicted as the DCT phase

P_{LFI}= Probability that the propagator (target ship system) will launch its weapon and control it to an intercept (i.e., a hit) with the target or control a defensive missile engagement to an intercept. This is a similar to $P_{I/L}$ times $P_{H/I}$ above and will be depicted as the engagement phase

VULNERABILITY DEFINITION

$P_{K|H}$ = Conditional probability that the ASCM is killed, given a hit by the propagator

Table 2. Probability Definitions used in this report.

The mapping of these probabilities is depicted in the decision tree diagram in Figure 1. This chart is derived from Ball's (2003, Figure 1.6) aircraft survivability text, but modified to depict the survivability of an ASCM instead of an aircraft. Note that this diagram represents a single shot/single intercept scenario between a SAM system and the ASCM. All probabilities listed are applicable to this modification. The key differences between the aircraft model and the ASCM model are the values associated with the functions that affect ASCM survivability. Even where the functions are similar, the values assigned to the probability are likely to be very different. For example, the probability of an aircraft being detected would be different from an ASCM being detected. This is due to the ASCM typically having a lower radar cross section (RCS) and a lower ingress altitude, making it more difficult to detect initially. During the ships detection, targeting, and engagement phases (Nodes (2) and (3) in Figure 1), the ASCM is in an autonomous search mode. An aircraft in a similar position would also be in a search mode, but it would allow for human intervention (such as maneuvering). Since ASCMs do not carry aircrew, the only potential human intervention would be a human-initiated self-destruct mechanism. If a decision were made to early self-destruct, the target ship would credit itself with an unearned kill. Human survivability aboard the ASCM is not a concern, whereas it is a big concern for aircraft designs.

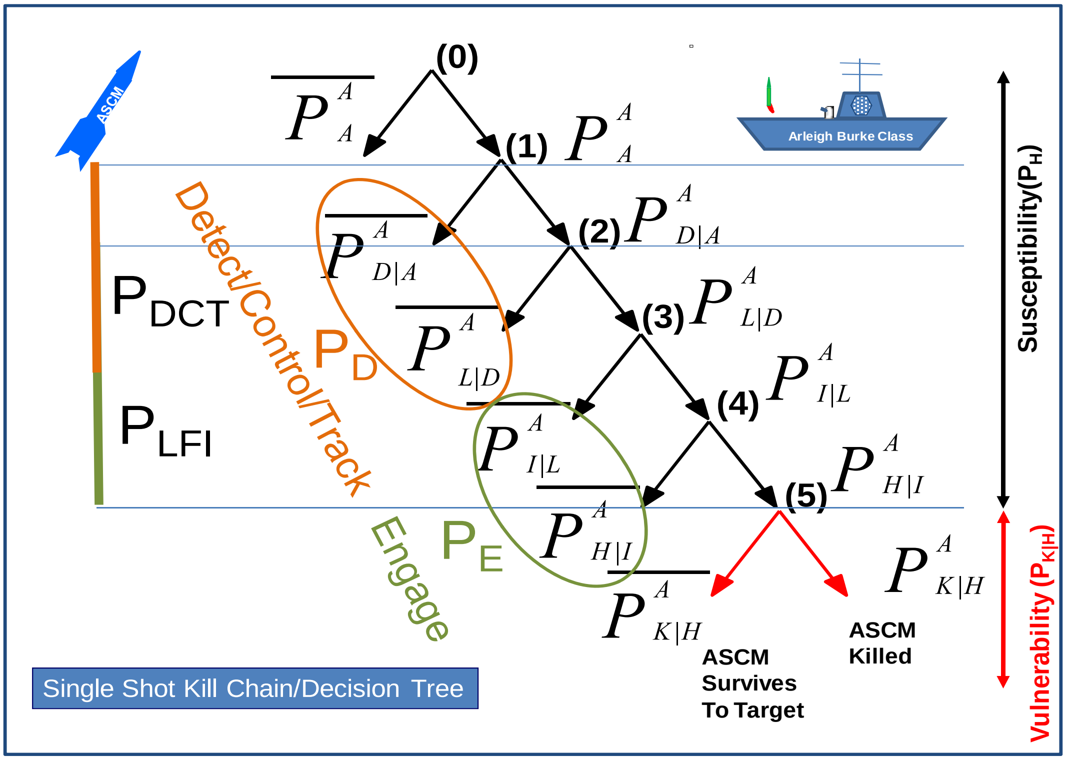

Figure 1. Anti-Ship Cruise Missile Kill Chain Tree Diagram (after Ball 2003).

For this analysis, the Ball and Calvano (1994) definitions are used. These are tailored for studying the kill chain from the target ship's perspective where the ship is being pursued by an airborne threat. This point of view is depicted on the left side of Figure 2. This paper uses the same equations, but changes the point of view to be from an ASCM being attacked by a single missile or weapon (propagator) coming from the target ship. This view is seen on the right side of Figure 2. From the article (Ball and Calvano 1994), hitability is defined as:

(1) $P_H = P_A * P_{DCT} * P_{LFI}$

where $P_A = 1$ is assumed because the assumption is made that the target ship is prepared for battle in this case.

The equation in Ball and Calvano is from the ship's perspective. From the ASCM's point of view, the ASCM's survivability component for the susceptible phase (notated with the superscript A), is described by:

$$(2) \qquad P_S^A = 1 - P_{DCT}^A * P_{LFI}^A$$

Since the ship is assumed to be ready for an attack, an assumption is made that, if a threat is detected, the ship's defensive systems will be able to track it and classify it as a threat, and prosecute it. This assumption may be degraded eventually due to soft kill methods incorporated by the ASCM. Given this assumption,

$$(3) \qquad P_{DCT}^A = P_{D/A}^A = P_D^A$$

Similarly, it is assumed that if the target is classified as a threat and tracked, the target ship will launch an eligible missile to an intercept within its ability to meet the timing constraints. For now, the timing restraint is referring to the delay required for detection, tracking, reaction, and decision making.

$$(4) \qquad P_{LFI}^A = P_{L/D}^A * P_{I/L}^A = P_E^A$$

The final item in the Kill Chain, $P_{k/h}$, is a term associated with the vulnerability of the system being observed, the ASCM in this situation. Vulnerability, in this case, is the probability that the ASCM is destroyed to the point that it is not able to complete its mission. For this kill chain, the probability of kill would then be described as:

$$(5) \qquad P_K^A = P_D^A * P_E^A * P_{K/H}^A$$

And therefore, the probability of the ASCM surviving against one shot is:

$$(6) \qquad P_S^A = 1 - P_K^A = 1 - P_D^A * P_E^A * P_{K/H}^A$$

To analyze the various ASCMs, reasonable values for P_D. P_E, and $P_{K/H}$ will be derived for each missile engagement and used to solve Equation (6). Where analytical derivations are not possible, reasonable assumptions of performance will be made and the rationale will be provided.

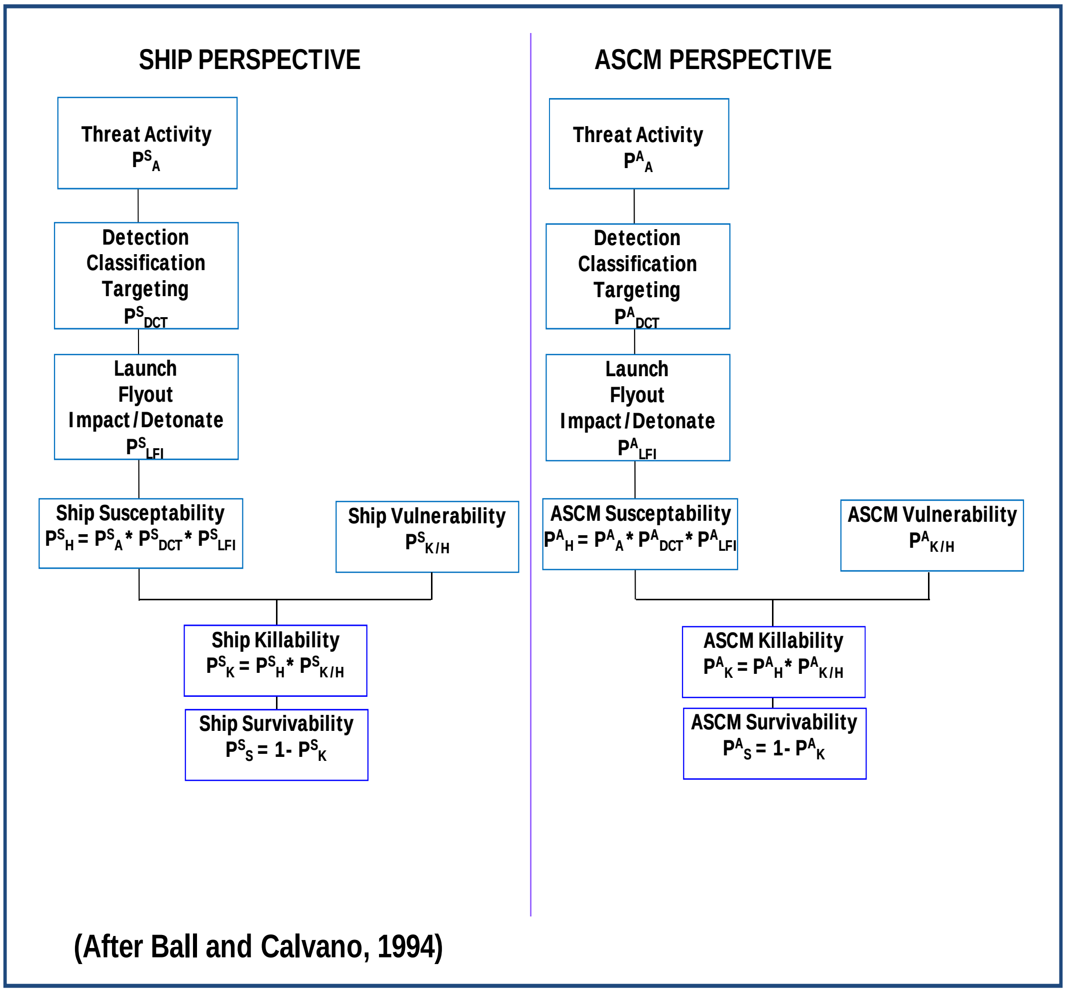

Figure 2. Probability definitions from the target ship and ASCM perspectives.

II. OPERATING ENVIRONMENTS

A. INTRODUCTION

The operating environments for this analysis are narrowed down to four specific cases. These cases represent typical operational scenarios for ASCMS employment as depicted in Figure 3. The analysis assumes the target ship to be at sea, within the targeting range of the ASCM, and ready to defend itself with available defenses. This paper only addresses survivability characteristics, i.e., susceptibility and vulnerability. Other "-ilities," such as availability, reliability, and supportability, are not assessed here.

The four cases are [A] surface-launched, [B] subsurface-launched, [C] land-launched, and [D] air-launched. Each case brings a unique challenge to the ASCM problem. This paper looks at these challenges to ascertain whether they bring a significant fidelity to the analysis to better understand how each is best defeated. A sampling of 19 real world anti ship cruise missiles collected from Jane's Naval Weapon Systems (http://search.janes.com) is listed in Table 20, Table 21, and Table 22 in the Appendix. To keep the study unclassified, only unclassified data was collected. The missiles identified in these tables are the missiles used in this study.

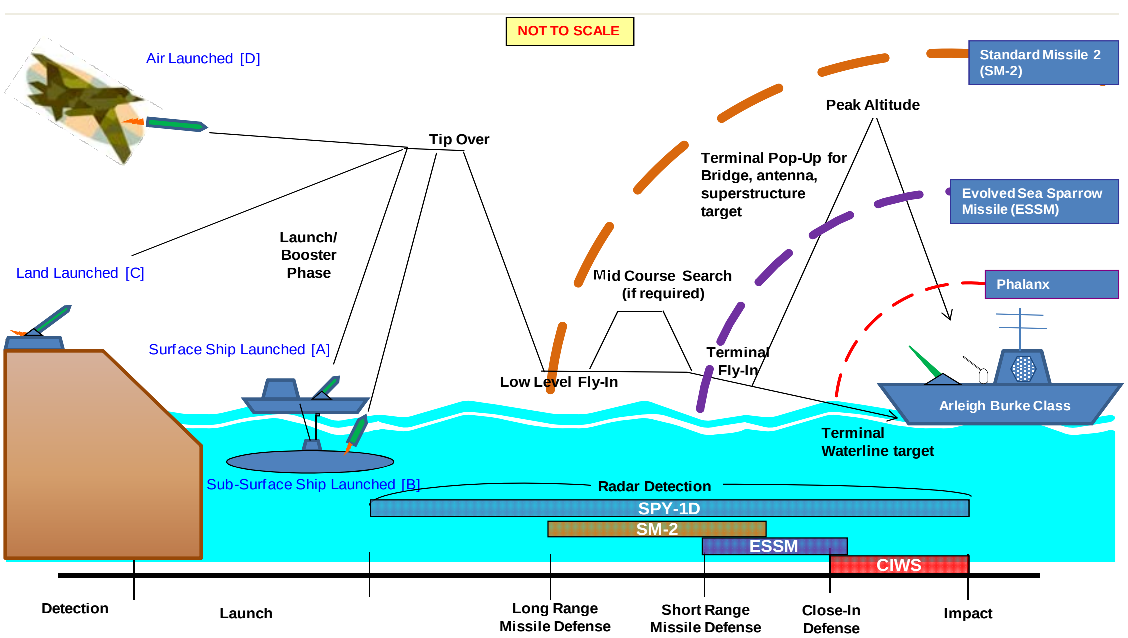

Figure 3. Typical Anti-Ship Cruise Missile (ASCM) profiles.

1. Surface Ship Launched ASCM [Case A]

a. The surface ship launched ASCM can be launched by any surface warship. Due to capability considerations, large warships such as destroyers and cruisers have the ability to carry larger missiles with larger, more complex payloads and longer effective ranges. Smaller ships such as patrol boats will likely carry missiles with limited range and payload capabilities. All ships have a limitation on the number of ASCMs available to launch, but small ships/boats will have greater limitations.

b. Surface ships rely on own-ship acquisition and Over-the-Horizon (OTH) methods for targeting. Many ships have long range early warning radars such as the SPS-49 and electronic surveillance/attack systems such as the SLQ-32. These systems alone usually lack complete targeting capability, however, since they can't ensure target allegiance and intent. Targeting can be augmented from other on-ship and off-ship sensors and sources. Although not relevant here, to defend themselves against ASCMs, most threat combatant ships will have a combination of long range surface to air missiles (such as the SA-N-6) and a point defense system comparable to the Phalanx CIWS, Russian AK-630, or a Chinese Type 730 CIWS.

2. Sub-Surface Launched ASCM [Case B]

a. The sub-surface launched ASCM is typically launched from a submarine at periscope depth or less. Most submarines have the ability to carry sophisticated ASCMs and can launch them while submerged.

b. Submarines can similarly rely on own-ship acquisition and OTH methods for targeting. Onboard sonar systems can provide additional acquisition support, but data for longer range shot's will likely come from off-board sources. Targeting can be accomplished by both means. It will be difficult for a ship to avoid detection by a subsurface threat, unless it has considerable anti-submarine warfare resources. Once an ASCM is launched and has broached the waterline, however, its profile will present similar challenges as ASCM's launched in the other regimes.

3. Land-Based Launched ASCM [Case C]

a. The land-based ASCM can be launched from a fixed ground site or from a vehicle. When ships are operating in the threat littoral regions, they are likely to be targeted by land-based ASCMs that have the range to reach them.

b. Land-based acquisitions are similar to their sea-borne relatives. Early acquisition data can be obtained by ground based early warning and targeting systems, or passed from ship or airborne team members via communications links. To defend against land-based ASCMs, ships will use the same suite of missiles and guns as in the surface and sub-surface scenarios. The best defense against a land-based ASCM is to avoid the threat engagement envelope. Unfortunately, littoral operations will not allow complete avoidance.

4. Air Launched ASCM [Case D]

a. The air launched ASCM is launched from either a fixed wing or rotary wing aircraft. The fixed wing aircraft can be a fighter aircraft or a larger patrol and surveillance aircraft. Rotary wing aircraft include helicopters or Unmanned Aerial Vehicles (UAVs) of varying sizes.

b Aircraft can rely on own-ship acquisition data and/or on externally provided targeting data. The aircraft launched ASCM may be smaller than average but may have longer effective range since the missile can be launched from a high altitude, reducing the energy required to reach target. The ship will defend against the air launched ASCM in a manner similar to the other launch scenarios. Early warning can potentially be obtained from the launch platform signatures in the RF, IR and visual regimes.

5. Threats to ASCMs

The target warship is a threat to the ASCM if it is aware that a threat is imminent. Its weapon system set is designed to create barriers to the ASCM success. Contributors to the kill chain effectiveness will be the long range SAM, the short range SAM, the close-in weapons system (CIWS), electronic RF jamming, IR/EO jamming, and use of decoys/flares/chaff.

B. SUMMARY

ASCM operating environments affect design parameters that affect execution profiles in turn. Although most ASCMS have a final target run in, the launch phase of each scenario varies. Air launched ASCMS can potentially have longer ranges due to launching at high altitude, but weight is limited which means lower explosive capability. Ship, submarine, and land launch sites can handle heavy weight missiles but the missiles have to use larger amounts of fuel to fly at low altitudes or to climb to high altitudes to achieve long range. Ships and submarine are mobile and can move to locations that favor them. Submarines can hide underwater and launch from almost anywhere. Land ASCMs can hide behind terrain features, but will eventually be range-limited to some maximum distance from shore.

III. RESEARCH ANALYSIS

A. INTRODUCTION

This section describes the decision tree and time line analysis methodologies for the selected ASCM missile system encounters with a target ship. Data for kill chain probabilities are derived from calculations and estimates of the factors in the kill chain model. These factors include variables such as estimates of intercept ranges, missile RCS, calculations of the number of shot opportunities, and estimates of electronic warfare system effectiveness (i.e., soft kills).

Analysis Methodology:

1. Decision Tree Analysis

Two software tools were used to analyze this problem. The first was a software product from the Palisade Corporation called @Risk for Excel (version 5.5) with Precision Tree and Monte Carlo simulation tools used as add-ins to Microsoft Excel. Second, Microsoft Excel was used with its graphing and analytical capabilities to derive time line charts for a time-line analysis. The @Risk program facilitates a decision tree and Monte Carlo analysis of the models developed. The kill chain, as described in Ball 2003 and shown in Figure 1, is modeled in the Decision Tree software and the results are shown in Figure 4. When soft kill characteristics were incorporated, the modified decision tree in Figure 5 can be used. Soft kill characteristics are added to the detection and engagement nodes at appropriate branches in the model where soft kill effects would be realized. All soft kill event branches are identical; however, values for each branch will likely vary. The soft kill event branches are Electronic Countermeasures (ECM), RF decoy, IR Decoy, and "Other." ECM addresses the probability of jamming used by the ASCM or a contributor on the ASCM side of the kill chain. The RF decoy can be either chaff or an actual decoy used by the ASCM forces or the ASCM itself. Flares are addressed in the UV/IR Decoy event branches. Chaff and RF decoys will be instrumental in defeating RF sensors on the target ship where flares and IR decoys will be instrumental

to the IR seekers. The "Other" event branch is reserved for all other cases—it was set to an arbitrary value to ensure the sum of the probabilities nodes add up to one which is a requirements in most decision-tree software programs.

The additional soft kill branches in Figure 5 reduce to the branches of Figure 4 when the soft kill branch probabilities are reduce to zero. In this case the ASCM survival is completely realized in the "other" branch and hence becomes redundant. With this approach, the model represented in Figure 5 can be used for both scenarios, i.e., both with and without soft kill measures.

Soft kill measures incorporated by the target ship should also be addressed in some analyses. To handle this case, the equation in the "ASCM KILLED" branches is modified to:

$$(7) \qquad P_K^A = P_{K(SAM)} + P_{K(Ship-SK)} - P_{K(ASCM-SK)}$$

Where $P_{K(SAM)}$ is the probability of kill associated with the SAM attacking the ASCM, $P_{K(Ship-SK)}$ is the probability that the ASCM will be killed by soft kill measures, and $P_{K(ASCM-SK)}$ is the reduction in the ship's probability of killing the ASCM due to ASCM-initiated soft kill measures. Hence, the ship soft kill features are additive to the probability of kill, while the ASCM soft kill measures are subtractive. In the model, the ship soft kill probabilities are inserted in the "TARGET SHIP SOFT KILL" bar where they are added the probability of kill for the respective phases. The soft kill probability is set to zero, when ship soft kill measures are assumed not to be employed.

Notice that when an ASCM successfully completes its mission, it is always on a "kamikaze" mission and is destroyed in the end. Hence, if costs are analyzed, the expected value of the ASCM in all missions is the full cost of the ASCM – regardless if it succeeds to the target or not; i.e., if an ASCM is launched, the total cost of the ASCM is expended. This is different from an aircraft model, because aircraft are generally expected to have a plan to return from a mission (unless carrying out a kamikaze mission).

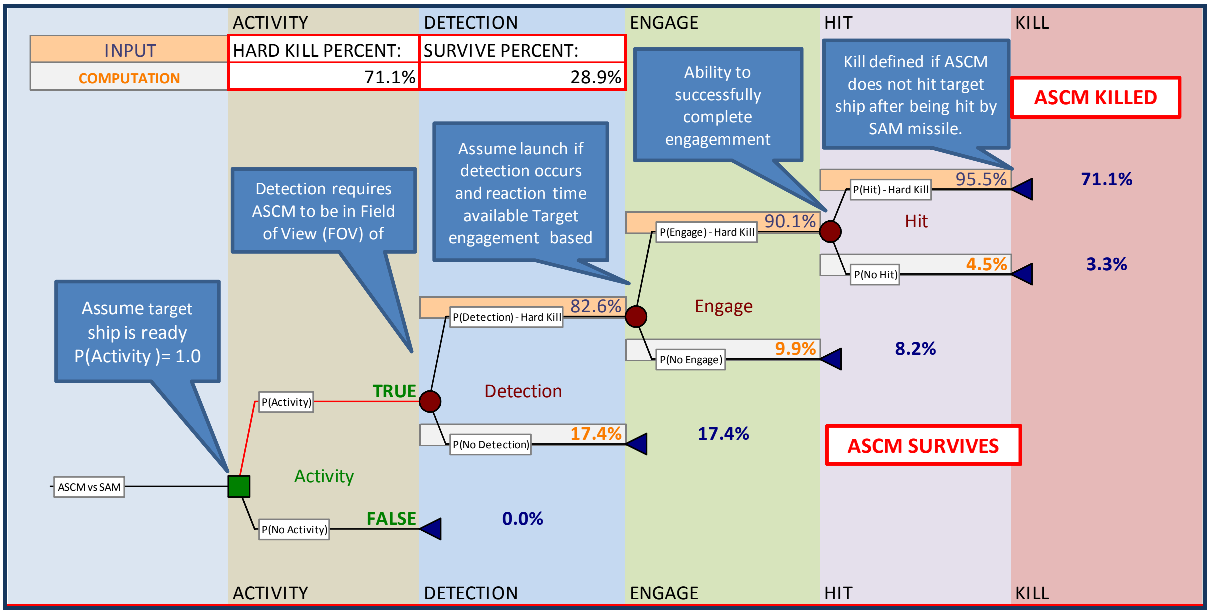

Figure 4. @Risk decision tree model of ASCM vs. SAM.

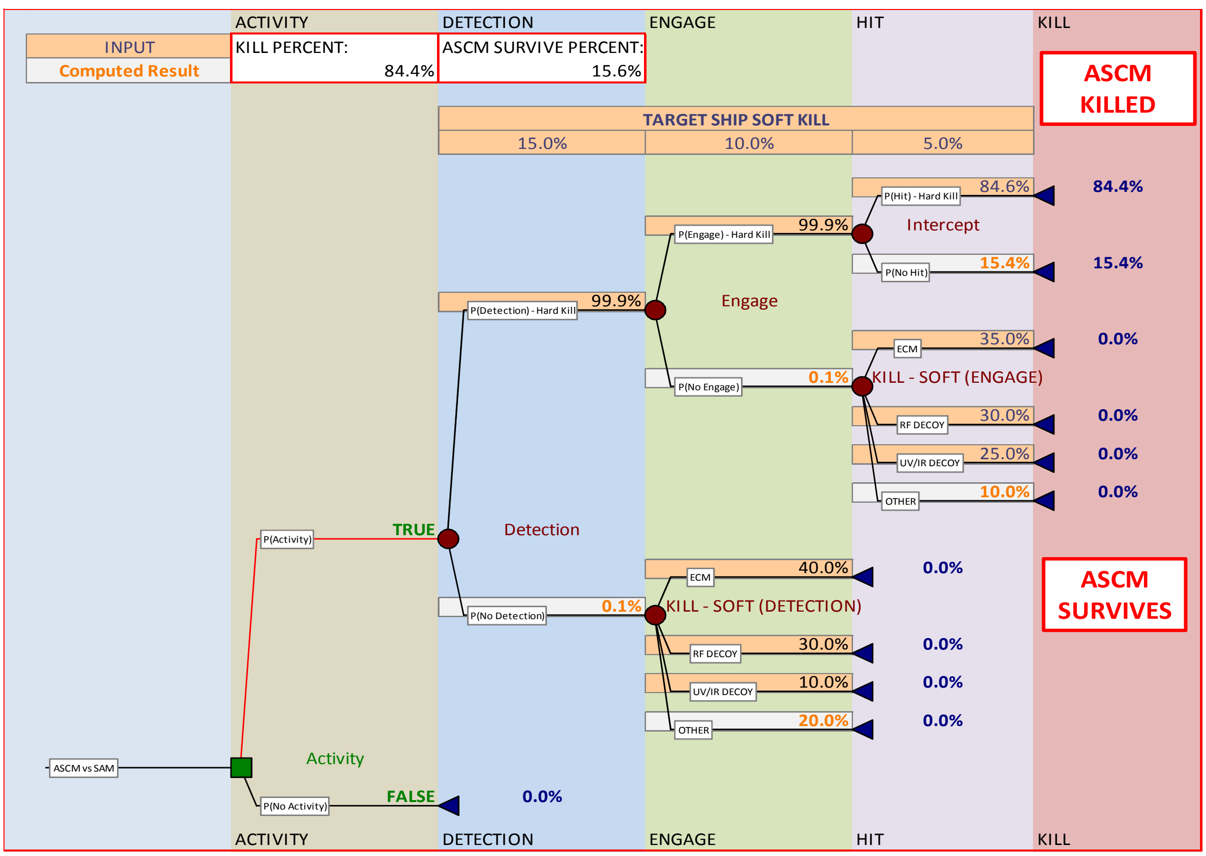

Figure 5. @Risk decision tree model of ASCM vs SAM with soft kill elaborated.

2. Time Line Analysis

The second type of analysis used in this study is the time line analysis. This was done with Microsoft Excel using its calculation and graphing features. The time line analysis gives a view of ASCM and defensive missile positions with respect to time. An assumption is made that the ASCM will acquire its target and proceed directly to the target for a "hit" and potential "kill." The ASCM will be active for a determinate amount of time equal to the ASCM's range divided by its speed. In real life, the ASCM will have varied speeds throughout its profile, but, the overall average speed is used to simplify the problem. Further, it is assumed that the ship's weapon systems will take as many shots as possible when the ASCM is in the engagement envelope of the ship's weapon system. When two systems could engage at the same time, the shorter range system is chosen to take the shot. An example problem is depicted in Figure 6. In this situation, the layered defense consists of a long range SAM (LRSAM), a short range SAM (SRSAM) and a Close-In Weapon System (CIWS). In the example shown, an ASCM with a 100 km range is launched against a target ship with these defensive systems. The ASCM's time-range profile is depicted by the single blue diagonal line with a negative slope going from left to right. This represents the ASCM closing speed of 700 km/hr (.57 Mach). The ship has many opportunities to launch its weapon systems against the ASCM in this scenario. These are depicted by the several color coded diagonal lines with positive slopes in Figure 6. Since the ASCM Max range is within the firing envelope of the LRSAM, the LR SAM can engage the ASCM between its max range and min range. In the example shown, the ship can launch its Mach 3.0 LRSAMs (pink lines in Figure 6). When the ASCM reaches the maximum range of the SRSAM, the Mach 3.5 SRSAM (green lines in Figure 6) engage instead of the LRSAM. Finally, the ASCM enters the CIWS range and is engaged by that system. In this example, the slope of the SRSAM is steeper due to the higher Mach 3.5 speed of the SRSAM over the Mach 3.0 speed of the LRSAM. In the example, each missile shot is assumed to be an independent event and is taken under a shoot-look-shoot policy. A ten second reaction time between consecutive shots is assumed. Under these conditions, if the ASCM survives, there are five possible shots from the SRSAM. As in the case of the LRSAM, the ASCM eventually exits the

SRSAM envelope and enters the close-in weapon system envelope. Hence the surviving ASCM goes through series of threats from the target ship;) three from the LRSAM, five from the SRSAM, and finally from the CIWS. The probability that an ASCM will killed is given by the multiplication of all the individual probabilities:

$$P_K = P_{K_1} * P_{K_2} * P_{K_3} * P_{K_4} * P_{K_5} * P_{K_6} * P_{K_7} * P_{K_8} * P_{K_9} \tag{8}$$

Where

$$P_{K_1} = P_{D\ LRSAM} * P_{E\ LRSAM} * P_{K/H\ LRSAM}\ at\ 78\ km \tag{9}$$

$$P_{K_2} = P_{D\ LRSAM} * P_{E\ LRSAM} * P_{K/H\ LRSAM}\ at\ 62\ km \tag{10}$$

$$P_{K_3} = P_{D\ LRSAM} * P_{E\ LRSAM} * P_{K/H\ LRSAM}\ at\ 47\ km \tag{11}$$

$$P_{K_4} = P_{D\ SRSAM} * P_{E\ SRSAM} * P_{K/H\ SRSAM}\ at\ 38\ km \tag{12}$$

$$P_{K_5} = P_{D\ SRSAM} * P_{E\ SRSAM} * P_{K/H\ SRSAM}\ at\ 30\ km \tag{13}$$

$$P_{K_6} = P_{D\ SRSAM} * P_{E\ SRSAM} * P_{K/H\ SRSAM}\ at\ 21\ km \tag{14}$$

$$P_{K_7} = P_{D\ SRSAM} * P_{E\ SRSAM} * P_{K/H\ SRSAM}\ at\ 16\ km \tag{15}$$

$$P_{K_8} = P_{D\ SRSAM} * P_{E\ SRSAM} * P_{K/H\ SRSAM}\ at\ 10\ km \tag{16}$$

$$P_{K_9} = P_{D\ CIWS} * P_{E\ CIWS} * P_{K/H\ CIWS}\ at\ 2\ km \tag{17}$$

The ASCM's survivability is the complement of the probability that it was killed, so the extension of Equation (6) for the multiple shots in this case is given by,:

$$P_S^A = \prod_{n=1}^{9} \left(1 - P_{K_n}\right)\ or\ \left(1 - P_{K_1}\right) * \left(1 - P_{K_2}\right) * \ldots * \left(1 - P_{K_9}\right) \tag{18}$$

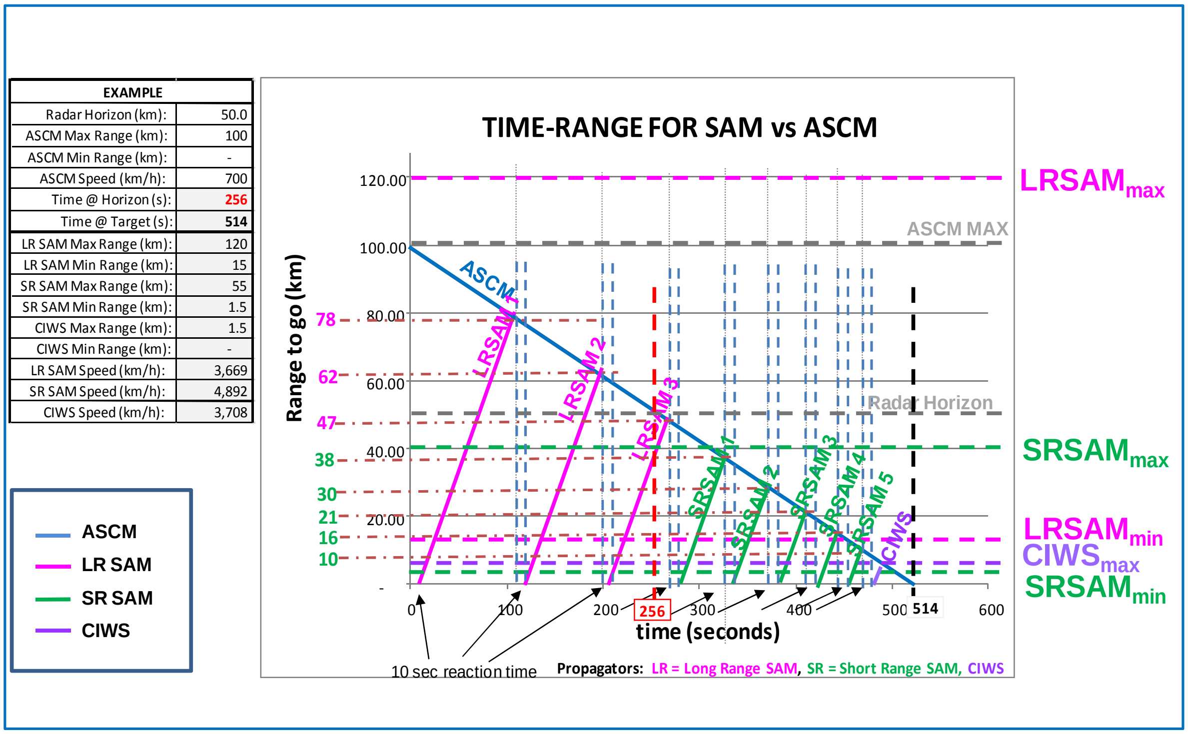

Figure 6. Generic time line diagram against a layered defense.

The time-line analysis shows the effects of speed, range, and timing of each hypothetical scenario but it does not show the effect of RCS reductions or Electronic Countermeasures (ECM). These effects are taken into account as a reduction in the probability of kill for each missile shot. Time lines for the 19 missiles chosen for this project are shown in Table 25 through Table 33 in the Appendix.

To complete the time line analysis, information on the maximum effective range and the radar horizon are needed. Equations for these from Ball (2003) are:

Radar Horizon

In U.S. units:

$$(19) \qquad R_H = 1.229\left(\sqrt{h_{Antenna}} + \sqrt{h_{ASCM}}\right)$$

where R_H is the horizon range in nautical miles, $h_{antenna}$ is the height of target ship antenna in feet, and h_{ASCM} is the altitude of the ASCM in feet when detected by target ship or in metric units:

$$(20) \qquad R_H = 4.124\left(\sqrt{h_{Antenna}} + \sqrt{h_{ASCM}}\right)$$

where R_H is the horizon range in kilometers, $h_{antenna}$ is the height of target ship antenna in meters, and h_{ASCM} is the altitude of the ASCM in meters.

Radar Range Equation

$$(21) \qquad R_{Max} = \left[\frac{P_r G_r^2 \lambda^2 \sigma}{(4\pi)^3 L_s L_a N (S/N)_{\min}}\right]^{1/4}$$

Where P_r = Power at the receiver, G_r = Gain at the receiver, λ = wavelength of detecting radar, σ = RCS of item being detected, L_s = Losses due to receiver path, L_a = Losses due to atmospheric conditions, N = Noise within receiver bandwidth, and $(S/N)_{min}$= minimum detectable signal to noise ratio. Many of these parameters are not readily available in the unclassified literature, so the following approach is used. If the maximum range of a radar is known for a given radar for a specified target for a given false alarm rate and a given signal to noise ratio, the relationship between signal to noise ratio, maximum range, and RCS can be used to calculate values at different ranges, RCSs, and signal to noise ratios.

From the radar range equation of Equation (21):

$$(22) \qquad R_{Max} \propto \left[\frac{\sigma}{(S/N)_{\min}}\right]^{1/4}$$

Harney (2004) introduces a new term for the signal to noise ratio, the Carrier Noise Ratio (CNR), which is the ratio of the mean signal power divided by the mean noise power. According to Harney, S/N_{min} should be defined differently, and for the purposes of this analysis, CNR is equal to what most books call S/N_{min}. This paper uses the term CNR to be consistant with the Harney's publication. Hence, Equation (22) can be rewritten as:

$$(23) \qquad R_{Max} \propto \left[\frac{\sigma}{CNR}\right]^{1/4}$$

Or

$$(24) \qquad CNR \propto \left[\frac{\sigma}{R^4}\right]$$

In the design of radars, two additional parameters are often combined with the CNR and provided as design specifications. They are the probability of detection (P_D), and the probability of false alarms (P_F). The relationships among CNR, P_D, and P_F are described as the Receiver Operating Characteristics (ROC) for a specific radar.

For the purposes of this study, the assumption is made that all targets are fluctuating with Swerling II statistics. This worst case assumption allows us to use the relationship of Equation 11.27 (Equation (25)) and Figure 11–8 in Volume 1 of Harney 2004 (Figure 7). An example is shown for a system with a P_D requirement of 90 percent and a P_F requirement of less than 1×10^{-8} which gives a CNR of 22.4 decibels (dB). These numbers can also be verified in equation form by using Equation (25).

From Harney 2004, the receiver operating characteristics for a Swerling II Target are described by:

$$(25) \qquad P_D = P_F^{\left(\frac{1}{1+CNR}\right)}$$

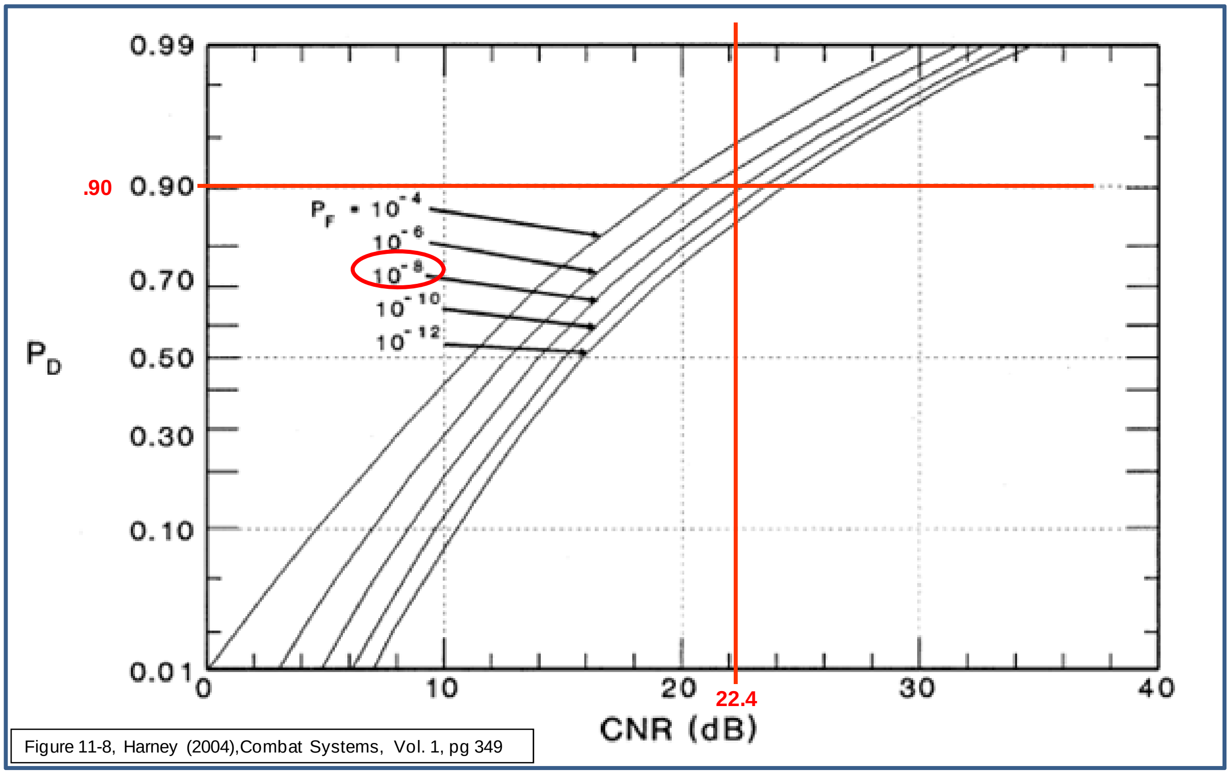

Figure 7. Receiver Operating Characteristics (ROC) for Swerling II targets.

Two other calculations are useful in this analysis, the RCS of a sphere and a cylinder. These calculations represent the extremes of the possible views that a radar would see against an incoming missile. The sphere can be used to approximate missile RCS when the missile is head on into the target. The head of the missile may actually be more of an ogive or cone which would reduce the reflection slightly. There will also be additional reflections from the fins. These two factors will be assumed to cancel each other in this analysis. The cylinder represents an approximation for when the missile is climbing or descending and a plan-form is shown to the target platform. Again, the additional inputs from the nose shape (causing a reduction) and fins (causing an increase) will be neglected. From Harney 2004, Volume 2, Table 2–2, the RCS of targets with spherical or cylindrical shapes can be estimated by:

Maximum RCS of a sphere

(26) $\sigma = \pi a^2 \rho$

Where a is the radius of object being detected or one half of the diameter of the ASCM and ρ is the target reflectivity. In most cases the target reflectivity can be assumed to be one.

Maximum RCS of a Cylinder

$$(27) \qquad \sigma = \left(\frac{2\pi L^2 a}{\lambda} \right) \rho$$

Where the aspect is taken normal to the axis, L= length, a=radius, λ = wavelength, and ρ is the target reflectivity (assumed to be one). For the cylinder, the maximum is achieved when the cylinder is orthogonal to the incoming RF energy.

B. KILL CHAIN PROBABILITIES

1. Probability of Detection

To analyze this problem, data from various phases of the kill chain are necessary. The first factor in the chain is the probability of detection of the ASCM by the target ship. Two scenarios are investigated. First, it is assumed that the ASCM can be detected at the maximum range of the ASCM and second, and more realistic, it is assumed that the ASCM will be detected at the radar horizon. Variances in ASCM diameters will cause a variance in RCS and variances in RCS will cause variances in probability of detection. Probabilities of detection are estimated using the Carrier-to-Noise equation, Equation (25) above, from Harney 2004. Probabilities of detection can be calculated for various ranges and various RCS values using the following equations. From Equation (26) and assuming that the reflectivity coefficient ρ is 1.0:

$$(28) \qquad \sigma = \pi a^2$$

When comparing two missiles of varying diameters, a_1 and a_2:

$$(29) \qquad \sigma_2 = \sigma_1 \left[\frac{a_1^2}{a_2^2} \right] = \sigma_1 \left[\frac{a_1}{a_2} \right]^2$$

Where a_1 is the reference missile diameter and a_2 is actual missile diameter of the missile of interest. In this case, all of the missiles looked at are compared to a reference

missile's diameter to get a relative measure of RCS for the particular missile. Next, the effect of range on CNR needs to be calculated for various ranges of interest to the problem.

To compare the same missile at two different ranges, from Equation (24):

$$(30) \qquad CNR \propto \left[\frac{\sigma}{R^4}\right]$$

To compare the CNR of a missile at two ranges R_1 and R_2, and knowing the CNR at one range (R_1), the CNR at the second range(R_2), can be computed by solving:

$$(31) \qquad CNR_2 = CNR_1\left[\frac{R_1^4}{R_2^4}\right] = CNR_1\left[\frac{R_1}{R_2}\right]^4$$

From the relationships above, the specification that a radar can detect a one square meter RCS target at 167 kilometers with a false alarm probability of $1x10^{-8}$, and a 90-percent probability of detection while providing a CNR of 22.4 dB, can be used to calculate other missiles' probabilities of detection for their different RCS values and at other ranges. This work is done in the spreadsheet Table 23 and Table 24 in Appendix A for the 19 ASCMs of this study and summarized in Table 3

These estimated probabilities are based on size in relationship to the spherical model and range only because these are assumed to be the worst case scenarios. Other factors such as different aspect ratios that would cause increased RCS are not addressed here but are candidates for further research.

Missile	Version	[A] Sea	[B] Sub	[C] Land	[D] Air	Diameter (cm)	ASCM Attack Altitude (m)	Speed (Mach)	Reference Range (km)	Max Range (km)	Radar Horizon (km)	Max Range (sec)	Radar Horizon (sec)	Probability of Detection at Reference Range	Probability of Detection at Max Missile Range	Probability of Detection at Radar Horizon Range
Exocet	MM38	X				35.0	3	0.9	167.0	40	24.1	131	52	35.4%	99.6%	100.0%
Exocet	MM40	X				35.0	3	0.9	167.0	70	24.1	229	150	35.4%	96.7%	100.0%
Harpoon	RGM-84	X				34.3	3	0.8	167.0	140	24.1	509	421	34.0%	57.7%	99.9%
Sizzler (91RE2)	SS-N-27	X				53.3	5	2.5	167.0	40	26.2	47	16	63.0%	99.8%	100.0%
Sizzler (3M-14E)	SS-N-27	X				53.3	5	0.9	167.0	300	26.2	981	895	63.0%	2.0%	100.0%
C-802 [Ship]	C-802	X				36.0	3	0.9	167.0	120	24.1	416	332	37.4%	76.1%	100.0%
Styx	SS-N-2	X				76.0	30	0.9	167.0	100	39.6	327	198	79.4%	97.0%	99.9%
Sunburn (Kh-41)	SS-N-22	X			X	76.0	3	3.0	167.0	100	24.1	98	74	79.4%	97.0%	100.0%
Switchblade	SS-N-25	X		X	X	42.0	2	0.8	167.0	130	22.8	478	394	48.0%	75.8%	100.0%
RBS-15	RBS-15	X		X	X	50.0	9	0.9	167.0	150	29.4	491	395	59.2%	70.9%	99.9%
Sunburn (3M-80E)	SS-N-22	X	X			130.0	20	3.0	167.0	120	35.4	118	83	92.4%	97.9%	100.0%
BrahMos	PJ-10	X	X	X	X	67.0	5	2.0	167.0	290	26.2	427	388	74.4%	9.3%	100.0%
Harpoon	UGM-84		X			34.3	3	0.8	167.0	140	24.1	509	421	34.0%	57.7%	99.9%
Exocet	SM39		X			35.0	3	0.9	167.0	50	24.1	164	85	35.4%	99.1%	100.0%
Silkworm	CSS-C-2			X		76.0	100	0.8	167.0	100	58.2	368	154	79.4%	97.0%	99.7%
Sardine	CSS-C-4			X		36.0	30	0.9	167.0	42	39.6	137	8	37.4%	99.6%	99.7%
Exocet	AM39				X	35.0	3	0.9	167.0	70	24.1	229	150	35.4%	96.7%	100.0%
Harpoon	AGM84				X	34.3	3	0.8	167.0	315	24.1	1,145	1,057	34.0%	0.0%	99.9%
C-802	CAS-8				X	36.0	3	0.9	167.0	130	24.1	450	367	37.4%	68.8%	100.0%

Table 3. Probability of Detection for Maximum Range and Radar Horizon

2. Probability of Engagement

The engagement phase is defined as the phase from the launch of the target ship's defensive missile to the intercept point with the ASCM. Factors affecting the engagement include obstacles to the target ship's ability to control a missile to an intercept with the incoming ASCM. A large obstacle that favors the ASCM over the target ship is the radar horizon. This can be controlled by having low run-in attack profiles. Another obstacle the ASCM can employ is speed. Speed will affect the amount of time the target ship can devote to defeating the ASCM. Another obstacle is range. The farther away the ASCM is from the target ship, the larger search is required by the target ship and the ASCM has a better chance of hiding its launch. Potentially, the

ASCM can also induce RF or IR interference to the target ship in the way of jamming or adding decoys to confuse or detract the target ship from its mission of defending itself.

Obstacles that need to be accounted for are the soft-kill features that could be emanating from the ASCM itself. These would directly impact the defensive systems capability to track and engage the ASCM before it attacks the target ship. Today's ASCMs do not employ this feature, mostly because including jamming features or decoys on the ASCM itself would directly reduce the amount of explosives that it could carry and thereby reduce its lethality. A more likely soft kill feature that may be employed is the launching of additional assets to help confuse the battle picture. Examples of possible assets are jamming platforms to support the ASCM attack or numerous credible decoys to overwhelm the ship's defensive command and control infrastructure.

An obstacle to the ASCM's success in attacking the ship is the soft-kill capability of the target ship. If the ship is jamming the ASCM missile seeker or launching chaff and/or decoys as a defense measure, the ASCM will need to take these features into account while prosecuting its target. This affects the engagement phase because the ASCM may be denied or delayed in obtaining its target (the target ship) in parallel to the hard kill measures that the defensive missile systems are employing. Hence the target ship could score a "mission success" (ASCM Killed) that is not related to the probabilities of success of the SAM kill chain. This would be counted as a soft kill by the target ship which is not addressed in this part of the study.

To handle the engagement phase, a simple model is used to develop an engagement envelope. The model assumes that if the detection has occurred, a high probability of success will be achieved by the target ship's defensive systems. This probability is reduced somewhat as the defensive system is near its maximum range or near its minimum range. These points are defined in the model and variations here can be assessed using the model. Figure 8 shows the values used for the three defensive systems, the LRSAM, the SRSAM, and the CIWS. To account for soft kill measures employed by the ASCM or its launch platform, the dashed lines are used. For the engagement phase, a ten percent reduction in probability of engagement is used.

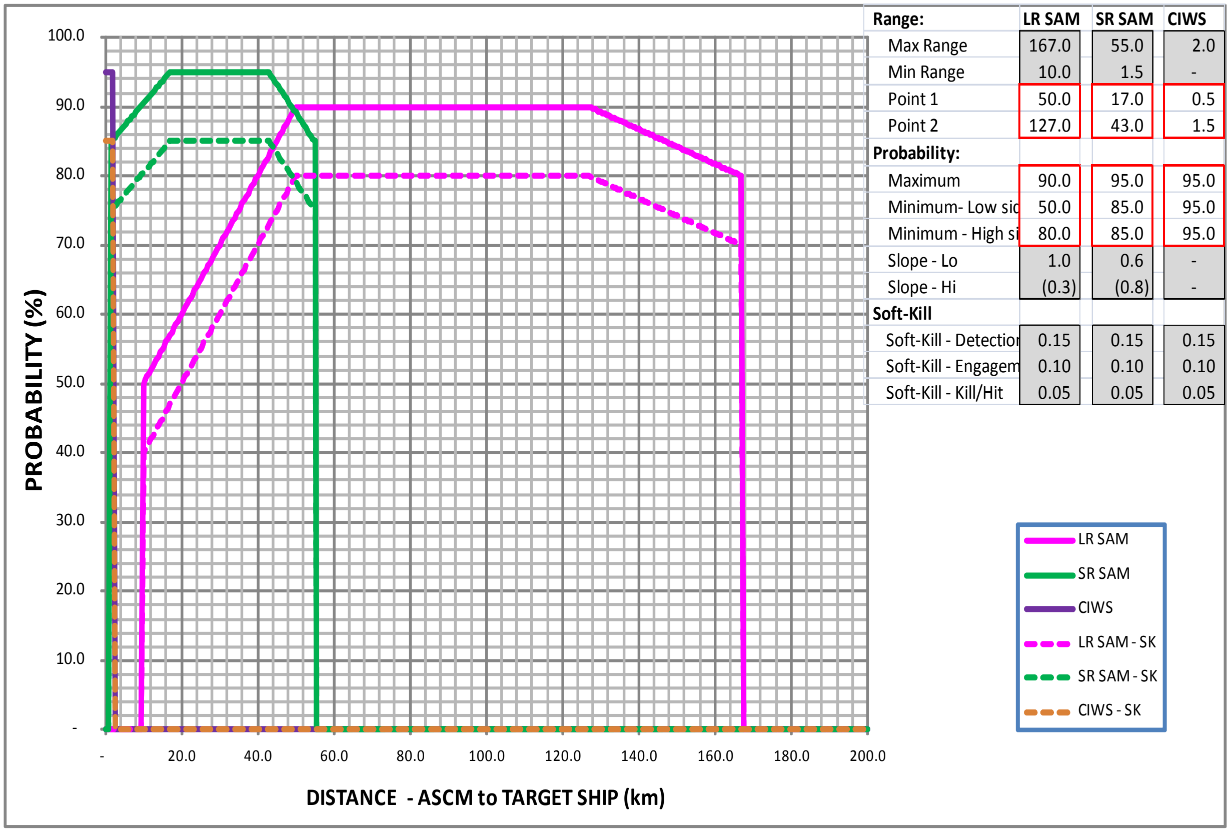

Figure 8. Probability of engagement envelopes used for simulation

3. Probability of Kill

The “kill” phase assumes that the ASCM has been detected, and a missile has successfully engaged the ASCM to impact or to a lethal fusing range. In most cases, an ASCM that has been successfully hit will not complete its mission and will be credited as a hard kill (mission success) to the target ship and a hard kill (mission failure) to the ASCM. Typical vulnerability enhancements that might reduce the probability of ASCM kill include (from Ball 2003) adding extra armor with rugged construction, using non flammable components and fuel, and inclusion of redundancy in the design. It is assumed that a design trade will be made to not overspend in these areas due to cost. These factors would add weight and complexity and potentially reduce the ASCMs capability to carry an effective payload to its target. We assume these enhancements are not used by the ASCM, hence, a probability of kill of 95 percent is assumed across the

board for this part of the problem. This number is reduced when soft-kill measures are present. A 10 percent reduction is applied to account for this effect.

C. DETAILS OF LINE DIAGRAM ANALYSIS

1. Detection/Engagement Probabilities

The spreadsheets shown in Table 23 and Table 24 of the appendix were used to calculate RCS and probability of detection at various ranges for the selected ASCMS. Table 23 uses Equations (19) through (31) to compute the probability of detection of an ASCM from the target ship's radar system using the ASCM's physical characteristics and expected target ship radar characteristics. In this case, the ASCM characteristics used are its diameter (which provides a basis for calculating RCS), attack altitude (basis for radar horizon or detection range), and speed. The ship characteristics used are radar mast altitude (basis for radar horizon), and radar detection specifications (probability of detection for a one square meter RCS target at 167 km is 90 percent with a probability of false alarms equal to $1x10^{-8}$). The time-line diagrams Table 25 through Table 33 in the appendix were used to compute ranges that the target ship would use to defeat the incoming ASCM. This information is compiled into the tables below. Table 4 shows results of these calculations for range. The column labeled "R1" displays the intercept ranges for the first missile fired at the ASCM. The column labeled "R2" has the intercept range for the second missile, etc.

Table 4 through Table 12 are color-coded similarly to the time-line diagrams in Figure 6 where pink represents the LRSAM engagement phase, green represents the SRSAM phase, and purple represents the CIWS phase. Brown shading was added to represent conditions for which the ASCM is below the radar horizon from the perspective of the target ship. For determining the radar horizon range, the target ship's radar mast height was assumed to be 17 meters and the ASCM's attack altitude in meters was used to calculate the radar horizon (Equation (20)). This table highlights the speed and radar horizon features discussed earlier. Slower and fatter ASCMs such as the Silkworm CSS-C-2 are visible from a long range and the target ship defensive systems have numerous opportunities to kill it. Short range missiles such as the Sizzler 91RE2 and Sardine are

never obstructed by the radar horizon, but the high speed (M2.5 vs. M.9) of the Sizzler reduces the opportunities to shoot it down. Time line analysis indicates there are six shot opportunities against the Sardine compared to only three for the Sizzler.

RANGE		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	**Version**	R1	R2	R3	R4	R5	R6	R7	R8	R_{CIWS}
Exocet	MM38	32	23	16	9	5				2
Exocet	SM39	42	38	19	12	8				2
Exocet	MM40	56	40	30	20	14	8			2
Exocet	AM39	56	40	30	20	14	8			2
Harpoon	RGM-84	103	78	55	39	25	18	9		2
Harpoon	UGM-84	103	78	55	39	25	18	9		2
Harpoon	AGM84	140	99	74	55	40	28	10		2
Silkworm	CSS-C-2	74	55	41	31	22	14	9	4	2
Sizzler (91RE2)	SS-N-27	22	7							2
Sizzler (3M-14E)	SS-N-27	122	80	65	42	26	19	8		2
Saccade C-802	CSSC-8/CSS-N-8	84	55	40	30	20	12	9		2
Saccade C-802	CAS-8	97	72	54	38	29	20	14	8	2
Sardine	CSS-C-4	33	23	15	9	4				2
Styx	SS-N-2D	73	54	39	28	19	11	7		2
Sunburn (3M-80E)	SS-N-22	55	23	7						2
Sunburn (Kh-41)	SS-N-22	51	20	6						2
Switchblade	SS-N-25	98	80	55	40	30	20	11	7	2
BrahMos	PJ-10	160	75	48	23					2
RBS-15 Mk 2	RBS-15	153	116	82	64	45	36	24	16	2

Table 4. Line diagram range results.

Table 5 and Table 6 show the probabilities of detection for the matching range cells in Table 4. Table 5 is for the case with no soft-kill mechanisms used by the ASCM and the numeric values do not take into account the radar horizon (despite the shading indicating over-the-horizon ranges). Table 6 adds in a correction factor for soft-kill measures when they are are used. In this case, a 15 percent drop in probability of detection is assumed. Using the methodology described here, the probabilities of detection for all of the missiles by the time they reach the radar horizon are almost 1.0. This means that the ASCM must do something to mitigate detection or it will be shot down, barring errors from the target ship's defensive team.

P(DETECTION)		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	Version	PD[R1]	PD[R2]	PD[R3]	PD[R4]	PD[R5]	PD[R6]	PD[R7]	PD[R8]	PD[R_{CIWS}]
Exocet	MM38	0.99862	0.99963	0.99991	0.99999	1.00000				0.95
Exocet	SM39	0.99591	0.99726	0.99983	0.99997	0.99999				0.95
Exocet	MM40	0.98713	0.99663	0.99893	0.99979	0.99999				0.95
Exocet	AM39	0.98713	0.99663	0.99893	0.99979	0.99999				0.95
Harpoon	RGM-84	0.85800	0.95061	0.98753	0.99683	0.99946	0.99986	0.99999		0.95
Harpoon	UGM-84	0.85800	0.95061	0.98753	0.99683	0.99946	0.99986	0.99999		0.95
Harpoon	AGM84	0.59902	0.87733	0.95978	0.98753	0.99649	0.99916	0.99999		0.95
Silkworm	CSS-C-2	0.99166	0.99745	0.99921	0.99974	0.99993	0.99999	1.00000	1.000000	0.95
Sizzler (91RE2)	SS-N-27	0.99987	1.00000							0.95
Sizzler (3M-14E)	SS-N-27	0.88247	0.97702	0.99359	0.99767	0.99974	0.99993	1.00000		0.95
Saccade C-802	CSSC-8/CSS-N-8	0.94006	0.98867	0.99682	0.99899	0.99980	0.99997	0.99999		0.95
Saccade C-802	CAS-8	0.89618	0.96714	0.98947	0.99741	0.99912	0.99980	0.99995	0.99999	0.95
Sardine	CSS-C-4	0.99852	0.99965	0.99994	0.99999	1.00000				0.95
Styx	SS-N-2D	0.99210	0.99763	0.99935	0.99983	0.99996	0.999996	0.999999		0.95
Sunburn (3M-80E)	SS-N-22	0.99876	1.00000							0.95
Sunburn (Kh-41)	SS-N-22	0.99811	0.99993							0.95
Switchblade	SS-N-25	0.91941	0.97574	0.99166	0.99766	0.99926	0.99985	0.99999		0.95
BrahMos	PJ-10	0.79239	0.98869	0.99809	0.99978					0.95
RBS-15 Mk 2	RBS-15	0.70668	0.88307	0.97127	0.98923	0.99736	0.99892	0.99977	0.99996	0.95

Table 5. Line diagram probability of detection results.

P(DETECTION-SK)		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	Version	PD[R1]	PD[R2]	PD[R3]	PD[R4]	PD[R5]	PD[R6]	PD[R7]	PD[R8]	PD[R_{CIWS}]
Exocet	MM38	0.84862	0.84963	0.84991	0.84999	0.85000				0.80
Exocet	SM39	0.84591	0.84726	0.84983	0.84997	0.84999				0.80
Exocet	MM40	0.83713	0.84663	0.84893	0.84979	0.84999				0.80
Exocet	AM39	0.83713	0.84663	0.84893	0.84979	0.84999				0.80
Harpoon	RGM-84	0.70800	0.80061	0.83753	0.84683	0.84946	0.84986	0.84999		0.80
Harpoon	UGM-84	0.70800	0.80061	0.83753	0.84683	0.84946	0.84986	0.84999		0.80
Harpoon	AGM84	0.44902	0.72733	0.80978	0.83753	0.84649	0.84916	0.84999		0.80
Silkworm	CSS-C-2	0.84166	0.84745	0.84921	0.84974	0.84993	0.84999	0.85000	0.85000	0.80
Sizzler (91RE2)	SS-N-27	0.84987	0.85000							0.80
Sizzler (3M-14E)	SS-N-27	0.73247	0.82702	0.84359	0.84767	0.84974	0.84993	0.85000		0.80
Saccade C-802	CSSC-8/CSS-N-8	0.79006	0.83867	0.84682	0.84899	0.84980	0.84997	0.84999		0.80
Saccade C-802	CAS-8	0.74618	0.81714	0.83947	0.84741	0.84912	0.84980	0.84995	0.84999	0.80
Sardine	CSS-C-4	0.84852	0.84965	0.84994	0.84999	0.85000				0.80
Styx	SS-N-2D	0.84210	0.84763	0.84935	0.84983	0.84996	0.85000	0.85000		0.80
Sunburn (3M-80E)	SS-N-22	0.84876	0.85000							0.80
Sunburn (Kh-41)	SS-N-22	0.84811	0.84993							0.80
Switchblade	SS-N-25	0.76941	0.82574	0.84166	0.84766	0.84926	0.84985	0.84999		0.80
BrahMos	PJ-10	0.64239	0.83869	0.84809	0.84978					0.80
RBS-15 Mk 2	RBS-15	0.55668	0.73307	0.82127	0.83923	0.84736	0.84892	0.84977	0.84996	0.80

Table 6. Line diagram probability of detection results with soft kill.

2. Engagement Probabilities

Figure 8 shows the probabilities attributed to the engagement phase for the three target ship defensive systems. These parameters are mapped into Table 7 and Table 8 in the same way that the detection probabilities were. The same color coding scheme applies. Table 7 represents the values if no soft kill is assumed and Table 8 assumes a 10 percent degradation due to soft-kill.

P(ENGAGEMENT) LRSAM SRSAM CIWS Radar Horizon

Missile	Version	PE[R1]	PE[R2]	PE[R3]	PE[R4]	PE[R5]	PE[R6]	PE[R7]	PE[R8]	PE[R_{CIWS}]
Exocet	MM38	0.95000	0.95000	0.94355	0.89839	0.87258				0.95
Exocet	SM39	0.95000	0.95000	0.95000	0.91774	0.89194				0.95
Exocet	MM40	0.90000	0.95000	0.95000	0.95000	0.93065	0.89194			0.95
Exocet	AM39	0.90000	0.95000	0.95000	0.95000	0.93065	0.89194			0.95
Harpoon	RGM-84	0.90000	0.90000	0.85000	0.95000	0.95000	0.95000	0.89839		0.95
Harpoon	UGM-84	0.90000	0.90000	0.85000	0.95000	0.95000	0.95000	0.89839		0.95
Harpoon	AGM84	0.86750	0.90000	0.90000	0.85000	0.95000	0.95000	0.90484		0.95
Silkworm	CSS-C-2	0.90000	0.85000	0.95000	0.95000	0.95000	0.93065	0.89839	0.86613	0.95
Sizzler (91RE2)	SS-N-27	0.95000	0.88548							0.95
Sizzler (3M-14E)	SS-N-27	0.90000	0.90000	0.90000	0.95000	0.95000	0.95000	0.89194		0.95
Saccade C-802	CSSC-8/CSS-N-8	0.90000	0.85000	0.95000	0.95000	0.95000	0.91774	0.89839		0.95
Saccade C-802	CAS-8	0.90000	0.90000	0.85833	0.95000	0.95000	0.95000	0.93065	0.89194	0.95
Sardine	CSS-C-4	0.95000	0.95000	0.93710	0.89839	0.86613				0.95
Styx	SS-N-2D	0.90000	0.85833	0.95000	0.95000	0.95000	0.91129	0.88548		0.95
Sunburn (3M-80E)	SS-N-22	0.85000	0.95000	0.88548						0.95
Sunburn (Kh-41)	SS-N-22	0.88333	0.95000	0.87903						0.95
Switchblade	SS-N-25	0.90000	0.90000	0.85000	0.95000	0.95000	0.95000	0.91129	0.88548	0.95
BrahMos	PJ-10	0.81750	0.90000	0.90833	0.95000					0.95
RBS-15 Mk 2	RBS-15	0.83500	0.90000	0.90000	0.90000	0.93333	0.95000	0.95000	0.94355	0.95

Table 7. Line diagram probability of engagement results.

P(ENGAGEMENT-SK) LRSAM SRSAM CIWS Radar Horizon

Missile	Version	PE[R1]	PE[R2]	PE[R3]	PE[R4]	PE[R5]	PE[R6]	PE[R7]	PE[R8]	PE[R_{CIWS}]
Exocet	MM38	0.85000	0.85000	0.84355	0.79839	0.77258				0.85
Exocet	SM39	0.85000	0.85000	0.85000	0.81774	0.79194				0.85
Exocet	MM40	0.80000	0.85000	0.85000	0.85000	0.83065	0.79194			0.85
Exocet	AM39	0.80000	0.85000	0.85000	0.85000	0.83065	0.79194			0.85
Harpoon	RGM-84	0.80000	0.80000	0.75000	0.85000	0.85000	0.85000	0.79839		0.85
Harpoon	UGM-84	0.80000	0.80000	0.75000	0.85000	0.85000	0.85000	0.79839		0.85
Harpoon	AGM84	0.76750	0.80000	0.80000	0.75000	0.85000	0.85000	0.80484		0.85
Silkworm	CSS-C-2	0.80000	0.75000	0.85000	0.85000	0.85000	0.83065	0.79839	0.76613	0.85
Sizzler (91RE2)	SS-N-27	0.85000	0.78548							0.85
Sizzler (3M-14E)	SS-N-27	0.80000	0.80000	0.80000	0.85000	0.85000	0.85000	0.79194		0.85
Saccade C-802	CSSC-8/CSS-N-8	0.80000	0.75000	0.85000	0.85000	0.85000	0.81774	0.79839		0.85
Saccade C-802	CAS-8	0.80000	0.80000	0.75833	0.85000	0.85000	0.85000	0.83065	0.79194	0.85
Sardine	CSS-C-4	0.85000	0.85000	0.83710	0.79839	0.76613				0.85
Styx	SS-N-2D	0.80000	0.75833	0.85000	0.85000	0.85000	0.81129	0.78548		0.85
Sunburn (3M-80E)	SS-N-22	0.75000	0.85000	0.78548						0.85
Sunburn (Kh-41)	SS-N-22	0.78333	0.85000	0.77903						0.85
Switchblade	SS-N-25	0.80000	0.80000	0.75000	0.85000	0.85000	0.85000	0.81129	0.78548	0.85
BrahMos	PJ-10	0.71750	0.80000	0.80833	0.85000					0.85
RBS-15 Mk 2	RBS-15	0.73500	0.80000	0.80000	0.80000	0.83333	0.85000	0.85000	0.84355	0.85

Table 8. Line diagram probability of engagement results with soft kill.

3. Kill/Hit Probabilities

Table 9 shows the probabilities attributed to the kill, given a hit, phase for the three target ship defensive systems. These parameters are mapped into Table 9 and Table 10 in the same way that the detection and engagement probabilities and were. The same color coding scheme applies. Table 9 represents the values if no soft kill is assumed and Table 10 assumes 5 percent degradation due to soft-kill.

P (KILL/HIT)		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	**Version**	PKH[R1]	PKH[R2]	PKH[R3]	PKH[R4]	PKH[R5]	PKH[R6]	PKH[R7]	PKH[R8]	PKH[R_{CIWS}]
Exocet	MM38	0.95	0.95	0.95	0.95	0.95				0.99
Exocet	SM39	0.95	0.95	0.95	0.95	0.95				0.99
Exocet	MM40	0.95	0.95	0.95	0.95	0.95	0.95			0.99
Exocet	AM39	0.95	0.95	0.95	0.95	0.95	0.95			0.99
Harpoon	RGM-84	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Harpoon	UGM-84	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Harpoon	AGM84	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Silkworm	CSS-C-2	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.99
Sizzler (91RE2)	SS-N-27	0.95	0.95							0.99
Sizzler (3M-14E)	SS-N-27	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Saccade C-802	CSSC-8/CSS-N-8	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Saccade C-802	CAS-8	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.99
Sardine	CSS-C-4	0.95	0.95	0.95	0.95	0.95				0.99
Styx	SS-N-2D	0.95	0.95	0.95	0.95	0.95	0.95	0.95		0.99
Sunburn (3M-80E)	SS-N-22	0.95	0.95	0.95						0.99
Sunburn (Kh-41)	SS-N-22	0.95	0.95	0.95						0.99
Switchblade	SS-N-25	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.99
BrahMos	PJ-10	0.95	0.95	0.95	0.95					0.99
RBS-15 Mk 2	RBS-15	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.99

Table 9. Line diagram probability of kill/hit results.

P(KILL/HIT-SK)		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	**Version**	PKH[R1]	PKH[R2]	PKH[R3]	PKH[R4]	PKH[R5]	PKH[R6]	PKH[R7]	PKH[R8]	PKH[R_{CIWS}]
Exocet	MM38	0.9	0.9	0.9	0.9	0.9				0.94
Exocet	SM39	0.9	0.9	0.9	0.9	0.9				0.94
Exocet	MM40	0.9	0.9	0.9	0.9	0.9	0.9			0.94
Exocet	AM39	0.9	0.9	0.9	0.9	0.9	0.9			0.94
Harpoon	RGM-84	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Harpoon	UGM-84	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Harpoon	AGM84	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Silkworm	CSS-C-2	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.94
Sizzler (91RE2)	SS-N-27	0.9	0.9							0.94
Sizzler (3M-14E)	SS-N-27	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Saccade C-802	CSSC-8/CSS-N-8	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Saccade C-802	CAS-8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.94
Sardine	CSS-C-4	0.9	0.9	0.9	0.9	0.9				0.94
Styx	SS-N-2D	0.9	0.9	0.9	0.9	0.9	0.9	0.9		0.94
Sunburn (3M-80E)	SS-N-22	0.9	0.9	0.9						0.94
Sunburn (Kh-41)	SS-N-22	0.9	0.9	0.9						0.94
Switchblade	SS-N-25	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.94
BrahMos	PJ-10	0.9	0.9	0.9	0.9					0.94
RBS-15 Mk 2	RBS-15	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.94

Table 10. Line diagram probability of kill/hit results with soft kill.

4. Survivability Probabilities

After the probabilities from each phase for each defensive attempt are captured; the overall probability of kill can be computed by multiplying the probability result of each missile. The equation for this is:

$$(32) \qquad P_K = \prod_{n=1}^{N} P_{K_n} = P_{K1} * P_2 * \dots * P_N$$

where

$$(33) \qquad P_{K_n} = P_{D_n} * P_{E_n} * P_{K/H_n}$$

n is the “nth” range point for each missile an *N* is the last system to engage the ASCM. From this data, the survivability can be computed using Equation(18):

$$(34) \qquad P_S = 1 - P_K = 1 - \left(P_1 * P_2 * \dots * P_n\right)$$

Table 11 and Table 12 show the probabilities of survival for the ASCM with respect to each individual target ship’s defensive missile shot. It includes the probabilities of detection, engagement, and kill, given a hit. These probabilities are mapped in the same way that the detection and engagement probabilities were in the previous tables. The same color coding scheme applies. Table 11 represents the values if no soft kill is assumed and Table 12 assumes the soft kill degradations by phase have been included (15 percent for detection, 10 percent for engagement, and 5 percent for kill/hit).

P(SURVIVABILITY)	= 1 - [P (Detection) * P(Engage) * P(Kill/Hit)]									
		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	**Version**	PS[R1]	PS[R2]	PS[R3]	PS[R4]	PS[R5]	PS[R6]	PS[R7]	PS[R8]	PS[R_{CIWS}]
Exocet	MM38	0.098746149	0.097832756	0.103706443	0.146539637	0.17104907				0.11
Exocet	SM39	0.101192438	0.099976144	0.09765498	0.128168985	0.152665864				0.11
Exocet	MM40	0.15600168	0.100539001	0.098462788	0.097690271	0.115894741				0.11
Exocet	AM39	0.15600168	0.100539001	0.098462788	0.097690271	0.115894741				0.11
Harpoon	RGM-84	0.266411544	0.187227929	0.202568827	0.100359862	0.097983595	0.097629989	0.146540509		0.11
Harpoon	UGM-84	0.266411544	0.187227929	0.202568827	0.100359862	0.097983595	0.097629989	0.146540509		0.11
Harpoon	AGM84	0.506333775	0.249882984	0.179390852	0.202568827	0.100664064	0.098260816	0.140415891		0.11
Silkworm	CSS-C-2	0.152132504	0.194562254	0.098212454	0.097732914	0.097559086	0.115896589	0.146533939	0.177177478	0.11
Sizzler (91RE2)	SS-N-27	0.097620128	0.15879147							0.11
Sizzler (3M-14E)	SS-N-27	0.245488737	0.164646119	0.150478586	0.099600263	0.097734323	0.097566831	0.152663408		0.11
Saccade C-802	CSSC-8/CSS-N-8	0.196245752	0.201646185	0.100372807	0.098410072	0.097679848	0.12816768	0.146539748		0.11
Saccade C-802	CAS-8	0.233769073	0.173096913	0.193169414	0.099840686	0.098294719	0.097679848	0.115932525	0.152665613	0.11
Sardine	CSS-C-4	0.098832091	0.097814529	0.109814201	0.146539233	0.17717806				0.11
Styx	SS-N-2D	0.151756367	0.186518628	0.09808333	0.097655025	0.097532871	0.134277736	0.158790929		0.11
Sunburn (3M-80E)	SS-N-22	0.193498975	0.097500862							0.11
Sunburn (Kh-41)	SS-N-22	0.162418366	0.097559086							0.11
Switchblade	SS-N-25	0.213906416	0.165743748	0.199230891	0.099611623	0.098168724	0.097632137	0.134286649		0.11
BrahMos	PJ-10	0.384610545	0.154667585	0.138728903	0.097699466					0.11
RBS-15 Mk 2	RBS-15	0.439427226	0.244972849	0.169562418	0.15420732	0.115677696	0.098478245	0.097707596	0.103666965	0.11

Table 11. Probability of survivability.

P(SURVIVABILITY-SK)										
		LRSAM	SRSAM	CIWS	Radar Horizon					
Missile	**Version**	PS[R1]	PS[R2]	PS[R3]	PS[R4]	PS[R5]	PS[R6]	PS[R7]	PS[R8]	PS[R_{CIWS}]
Exocet	MM38	0.350806293	0.350032059	0.354751048	0.389240084	0.408976379				0.36
Exocet	SM39	0.352879878	0.351848892	0.349881368	0.37444753	0.394173202				0.36
Exocet	MM40	0.397264573	0.352325996	0.350566103	0.349911282	0.364562915				0.36
Exocet	AM39	0.397264573	0.352325996	0.350566103	0.349911282	0.364562915				0.36
Harpoon	RGM-84	0.4902413	0.423560362	0.434666666	0.352174149	0.350159917	0.349860184	0.389240817		0.36
Harpoon	UGM-84	0.4902413	0.423560362	0.434666666	0.352174149	0.350159917	0.349860184	0.389240817		0.36
Harpoon	AGM84	0.689840384	0.476322513	0.416960717	0.434666666	0.352432005	0.350394902	0.38430906		0.36
Silkworm	CSS-C-2	0.394006319	0.427973866	0.350353908	0.349947429	0.349800084	0.364564478	0.389235286	0.41391134	0.36
Sizzler (91RE2)	SS-N-27	0.349851826	0.399105803							0.36
Sizzler (3M-14E)	SS-N-27	0.472622095	0.4045441	0.392613546	0.351530278	0.349948623	0.349806649	0.394171136		0.36
Saccade C-802	CSSC-8/CSS-N-8	0.431154317	0.433895418	0.352185122	0.350521419	0.349902447	0.374446429	0.389240177		0.36
Saccade C-802	CAS-8	0.462752904	0.411660559	0.42706151	0.351734072	0.35042364	0.349902447	0.364594864	0.394172991	0.36
Sardine	CSS-C-4	0.350879141	0.350016609	0.359668474	0.389239743	0.413911827				0.36
Styx	SS-N-2D	0.393689572	0.421494833	0.350244457	0.349881406	0.349777863	0.379365891	0.399105348		0.36
Sunburn (3M-80E)	SS-N-22	0.427085056	0.349750731							0.36
Sunburn (Kh-41)	SS-N-22	0.402081616	0.349800084							0.36
Switchblade	SS-N-25	0.446026455	0.405468419	0.431876441	0.351539907	0.350316841	0.349862005	0.379373409		0.36
BrahMos	PJ-10	0.585177014	0.396141124	0.383012332	0.349919076					0.36
RBS-15 Mk 2	RBS-15	0.631757127	0.472187662	0.408684142	0.395753533	0.364483014	0.350579205	0.349925967	0.354717611	0.36

Table 12. Probability of survivability with soft kill.

5. Summary

After multiplying the probability values, the results of Table 13 are obtained. The first column labeled P_s gives the result if over-the-horizon shots by the defending ship could be made throughout the ASCM profile when it is launched at its maximum range. The second column, P_s-R_h, gives the probabilities of survival if shots are only taken when the target ship can see the ASCM with its onboard radar. Columns 3 and 4 present the same data, but with soft kill measures factored in.

ASCM		Survivability		with Soft-Kill	
Missile	**Version**	P_S	P_S_R_H	P_S_SK	P_S_SK_R_H
Exocet	MM38	0.0%	0.0%	0.3%	0.7%
Exocet	SM39	0.0%	0.0%	0.2%	1.9%
Exocet	MM40	0.0%	0.0%	0.2%	4.6%
Exocet	AM39	0.0%	0.1%	0.2%	4.6%
Harpoon	RGM-84	0.0%	0.0%	0.1%	4.9%
Harpoon	UGM-84	0.0%	0.2%	0.1%	4.9%
Harpoon	AGM84	0.0%	1.5%	0.1%	0.0%
Silkworm	CSS-C-2	0.0%	0.0%	0.0%	0.0%
Sizzler (91RE2)	SS-N-27	0.2%	0.2%	5.0%	5.0%
Sizzler (3M-14E)	SS-N-27	0.0%	0.0%	0.0%	1.7%
Saccade C-802	CSSC-8/CSS-N-8	0.0%	0.0%	0.0%	1.8%
Saccade C-802	CAS-8	0.0%	0.0%	0.0%	0.0%
Sardine	CSS-C-4	0.0%	0.0%	0.3%	0.3%
Styx	SS-N-2D	0.0%	0.0%	0.0%	0.2%
Sunburn (3M-80E)	SS-N-22	0.2%	1.0%	5.4%	12.6%
Sunburn (Kh-41)	SS-N-22	0.2%	9.8%	5.1%	0.6%
Switchblade	SS-N-25	0.0%	1.3%	0.0%	4.8%
BrahMos	PJ-10	0.0%	1.0%	1.1%	35.0%
RBS-15 Mk 2	RBS-15	0.0%	0.1%	0.0%	4.5%

Table 13. Summary of probability results for ASCM survivability.

D. DETAILS OF MONTE CARLO ANALYSIS

1. Probability Derivation

A Monte Carlo simulation was undertaken as a means to estimate the combined effects of the kill chain phases described above. The advantage of a Monte Carlo simulation over a simple multiplication of probabilities is that it provides the probability distribution of the output. The simulation provides point estimates for overall ASCM

survivability, as well as other statistics (maximum, minimum, standard deviation, etc.). The inputs to the Monte Carlo simulation are the probabilities for each phase in the kill chain, which were randomized using the probability distributions described below. The outputs are estimates of overall ASCM survivability probabilities and their statistics.

One benefit of using decision tree software is that it facilitates doing a Monte Carlo simulation to provide insight on of probability characteristics that can be expected using the assumptions made. The decision tree software allows any variable in the tree to be varied using standard or self defined probability distribution. In the decision tree model, there are a couple of candidates for using this capability. Each SAM shot is an independent event that has a probability associated with its potential for success. Soft kill measures can also be applied and an associated probability can be given to its affect. Since the SAM shots against the ASCM are discrete, independent events that have only two possible results – success (ASCM Killed) or failure (ASCM Survives). This picture is true for each phase of the intercept. In the detection phase, the ASCM is either detected or not detected; in the engagement phase, the ASCM is either engaged by the SAM system or not engaged; and in the Kill/Hit phase, it either reaches the intercept and kills the ASCM or it doesn't. Further, a probability of success (or failure) can be attributed to each phase of the intercept. Hence a binomial distribution is appropriate for simulation of each phase of the SAM intercept with the ASCM. The soft kill measures, on the other hand, provide a different probability situation to the problem. There are two different soft kill measures that should be addressed. First, there is the soft kill measure attributed to the ship's defense that are working in parallel with the SAM to prevent the ASCM from attacking the ship. Second, there are soft kill measures associated with the ASCM attack to enhance its success in attacking the ship. As stated earlier, these measures are more likely to be on other platforms and not on the ASCM, but their effect on the problem is the same. The ASCM-side soft kill measures are additive to the ASCM's success where the target ship-side soft kill measures are subtractive to the ASCM's success. In the decision model, the ASCM-side soft kill measures are included in the down sloping decisions and can be mapped into the four categories shown; ECM, RF Decoy, IR/UV decoy, and "other" which is used to catch any other measure such as

luck. The target ship-side soft kill measures are included in the bar at the top and added to the probability equations on the upward branches of the decision model. For the purposes of the study, the ASCM-side soft kill measures are added to the model directly by phase. This is similar to the approach taken in the time line analysis and restricts the soft kill probability values in the problem to the kill side of the decision tree. In one analysis case, the ship side soft kill measures are also allowed to vary. These are varied by assuming a normal distribution around the expected probability value with a standard deviation equal to one third of the probability value.

For the binomial distributions of the three phases, probability of detection values were taken from the time line analysis. In most cases there were several shots taken against the ASCM, hence only the first shot after the ASCM breaks through the radar horizon was used for modeling and simulating each ASCM. The timeline values for this range were taken for the probability of detection, probability of engagement, and the probability of kill given a hit. A binomial distribution asks for two inputs, "*n*" and "*P*." *P* values were directly inserted as described above. Values for "*n*" were chosen from looking at the time line analysis. Since most shots were taken by the SRSAM, a decision was made to use only the SRSAM probability distribution and shot numbers. The value inserted for *n* was the number of shots that the SRSAM would take in the time line analysis, even though the simulation is only addressing one shot – the shot after breaking through the radar horizon. The other parameter needed for a Monte Carlo analysis is the number of simulations to carry out. According to www.janes.com, a similar missile, the Evolved Sea Sparrow Missile (ESSM) is expected to have a total production of three thousand. An arbitrary decision to use one third of that amount or one thousand trials was used in the simulation for each missile. The base probabilities for each phase of each missile engagement are listed in Table 14. The number of shots taken from the time line analysis is listed in the first three columns following the ASCM name and version (columns 3–5). The LRSAM shots and the SRSAM shots are tallied separately then totaled in the fifth column. As stated earlier, the model uses the SRSAM column values for *n*. The next three columns are probabilities of kill for the three phases that are inserted into the decision tree model. The last three columns show the probabilities

adjusted for ASCM-side soft kill measures. The same degradation values for the ASCM soft kill phase that were used in the timeline analysis were used in the Monte Carlo simulation. A fifteen percent reduction was assumed for detection, ten percent for engagement, and ten percent for kill, given a hit. The results of the Monte Carlo simulations for the selected ASCMs are included in the appendix in Table 34 through Table 67 and summarized in Table 15. Note that the results of Table 15 need to be compared to the result single shot result in Table 11 and Table 12 that gives the result for the first shot taken after passing the radar horizon because that is where the Monte Carlo data is from.

MONTE CARLO INPUT DATA								SOFT KILL DEGRADATION		
								15.0%	10.0%	5.0%
Missile	**Version**	**LRSAM**	**SRSAM**	**Total**	**P_D**	**P_E**	**$P_{H/K}$**	**P_D**	**P_E**	**$P_{H/K}$**
Exocet	MM38		5	5	0.9996	0.95	0.95	0.8496	0.85	0.90
Exocet	SM39		5	5	0.9998	0.95	0.95	0.8498	0.85	0.90
Exocet	MM40	1	4	5	0.9998	0.95	0.95	0.8498	0.85	0.90
Exocet	AM39	1	4	5	0.9998	0.95	0.95	0.8498	0.85	0.90
Harpoon	RGM-84	2	5	7	0.9999	0.95	0.95	0.8499	0.85	0.90
Harpoon	UGM-84	2	5	7	0.9999	0.95	0.95	0.8499	0.85	0.90
Harpoon	AGM84	3	4	7	1.0000	0.95	0.95	0.8500	0.85	0.90
Silkworm	CSS-C-2	1	7	8	0.9974	0.95	0.95	0.8474	0.85	0.90
Sizzler (91RE2)	SS-N-27		2	2	0.9999	0.95	0.95	0.8499	0.85	0.90
Sizzler (3M-14E)	SS-N-27	3	4	7	0.9997	0.95	0.95	0.8497	0.85	0.90
Saccade C-802	CSSC-8	1	6	7	0.9998	0.95	0.95	0.8498	0.85	0.90
Saccade C-802	CAS-8	2	6	8	0.9998	0.95	0.95	0.8498	0.85	0.90
Sardine	CSS-C-4		5	5	0.9985	0.95	0.95	0.8485	0.85	0.90
Styx	SS-N-2d	1	6	7	0.9994	0.95	0.95	0.8494	0.85	0.90
Sunburn (3M-80E)	SS-N-22	1	1	2	1.0000	0.95	0.95	0.8500	0.85	0.90
Sunburn (Kh-41)	SS-N-22		2	2	0.9999	0.95	0.95	0.8499	0.85	0.90
Switchblade	SS-N-25	2	5	7	0.9999	0.95	0.95	0.8499	0.85	0.90
BrahMos	PJ-10	2	2	4	0.9998	0.95	0.95	0.8498	0.85	0.90
RBS-15 Mk 2	RBS-15	4	4	8	0.9998	0.95	0.95	0.8498	0.85	0.90

Table 14. Monte Carlo input probabilities used for simulation.

			ASCM ONLY				ASCM + ASCM SK				ASCM + ASCM SK + SHIP SK			
Missile	Version	SRSAM N	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev
Exocet	MM38	5	0.000%	76.000%	9.720%	0.13184	27.325%	75.775%	35.023%	0.10171	0.300%	61.603%	11.385%	0.12706
Exocet	MM40	4	0.000%	75.000%	9.713%	0.14965	27.325%	84.700%	34.932%	0.11771	0.300%	73.442%	12.840%	0.14219
Exocet	SM39	5	0.000%	75.000%	9.756%	0.14668	27.325%	80.875%	34.996%	0.10312	0.300%	65.117%	12.776%	0.12790
Exocet	AM39	4	0.000%	75.000%	9.713%	0.14965	27.325%	84.700%	34.932%	0.11771	0.300%	73.442%	12.840%	0.14219
Harpoon	RGM-84	5	0.000%	60.000%	9.776%	0.13074	27.325%	85.975%	34.984%	0.10289	0.300%	65.265%	12.778%	0.12814
Harpoon	UGM-84	5	0.000%	60.000%	9.776%	0.13074	27.325%	85.975%	34.984%	0.10289	0.300%	65.265%	12.778%	0.12814
Harpoon	AGM84	4	0.000%	75.000%	9.731%	0.14828	31.150%	77.900%	38.555%	0.11092	0.300%	76.369%	11.589%	0.14320
Silkworm	CSS-C-2	7	0.000%	59.184%	9.992%	0.11131	27.325%	80.233%	35.186%	0.08769	0.300%	52.384%	11.491%	0.10633
Sizzler (91RE2)	SS-N-27	2	0.000%	100.000%	9.900%	0.20825	27.325%	84.700%	34.727%	0.15555	0.300%	99.561%	11.273%	0.20143
Sizzler (3M-14E)	SS-N-27	4	0.000%	75.000%	9.819%	0.14530	31.150%	88.525%	38.616%	0.11312	0.300%	81.068%	11.598%	0.14598
Saccade C-802	C-802	6	0.000%	66.667%	9.778%	0.12193	27.325%	81.158%	35.026%	0.09322	0.300%	59.318%	11.272%	0.11982
Saccade C-802	CAS-8	6	0.000%	66.667%	9.742%	0.12151	27.325%	73.367%	34.962%	0.09429	0.300%	67.901%	11.287%	0.11639
Sardine	CSS-C-4	5	0.000%	64.000%	9.912%	0.13136	27.325%	75.775%	35.111%	0.10311	0.300%	69.215%	11.384%	0.13080
Styx	SS-N-2	6	0.000%	66.667%	9.803%	0.12371	27.325%	71.950%	35.061%	0.09225	0.300%	57.841%	12.723%	0.11764
Sunburn (3M-80E)	SS-N-22	1	0.000%	100.000%	9.800%	0.29746	27.325%	**27.325%**	**27.325%**	-	0.300%	99.965%	**5.755%**	0.18948
Sunburn (Kh-41)	SS-N-22	2	0.000%	100.000%	9.850%	0.20879	27.325%	84.700%	34.818%	0.15661	0.300%	99.817%	11.334%	0.20134
Switchblade	SS-N-25	5	0.000%	60.000%	9.788%	0.13151	27.325%	80.875%	34.979%	0.10420	0.300%	69.666%	12.800%	0.12635
BrahMos	PJ-10	2	0.000%	100.000%	9.700%	0.20739	27.325%	84.700%	34.673%	0.15616	0.300%	99.411%	11.283%	0.20381
RBS-15	RBS-15	4	0.000%	62.500%	9.806%	0.14422	31.150%	91.713%	38.589%	0.11154	0.300%	62.846%	11.635%	0.13944

Table 15. Summary of Monte Carlo Probability of Survivability Results (1,000 Runs).

E. DATA ANALYSIS SUMMARY

1. Timeline Analysis

The time line analysis provides a response to the question "How many missiles could logically be used against an incoming ASCM?" From the analysis results and given assumptions, a highly capable target ship would have a high probability of success against the majority of ASCMs considered in the analysis.

The timeline analysis provided insight into the effects of ASCM radar cross section (RCS), speed, and use of countermeasures (soft-kill techniques) on the ability of the ASCM to penetrate shipboard defenses. An ASCM designer can use RCS to minimize its exposure, but a difference of at least one order of magnitude is needed to

have any significance. The difference in probability of detection for the very large, 130 cm diameter Sunburn (probability of detection at 35 km equals .979) and a much smaller 35 cm diameter Exocet MM-38 (probability of detection at 24 km equals .996) is statistically insignificant. Using the RCS-radar range model and Microsoft Excel's "goal seek" feature, an ASCM diameter can be found to meet criteria where a chance of survival is possible. Using 90 percent probability of kill by the target ship SAM as the break point, an ASCM would have to have an RCS equivalent to that of a missile with a diameter of 2.4 cm to achieve the 90 percent probability of detection using the spherical model. In reality, making the ASCM that small is not an option and other RCS reduction measures such as using radar absorbing materials and shape modifications are more likely to be seen.

Speed provided a bigger impact on ASCM survivability and success than RCS. From the data, the high speed ASCMs all had very limited number of potential intercepts. Since the probabilities are multiplicative, the probability of survivability increases as fewer target ship defensive missile shots are taken against the ASCM, thereby increasing the ASCMs probability of survival.

If soft kill measures can be employed in support of the ASCM, the probability of kill for the target ship defensive system is reduced and the ASCM's survivability is enhanced even more. In the analysis results, the high speed Sizzler 91RE2, Sunburn 3M-80E, Sunburn Hh-41 and the Brahmos ASCMs clearly demonstrate this characteristic. Although there was no significant difference for the first defensive missile shot, shortening the kill chain and adding soft kill measures had a big impact on the Sunburn 3M-80E and the Brahmos where the relatively small decrease in probability due to soft kill raises their chances of surviving from around zero to 15 percent and 39 percent respectively.

Table 16 summarizes the comparisons in the data with respect to operational scenario, speed, size, and radar horizon. It can be seen here that operational scenario and size did not create big differences. Differences were only substantial when range was limited to the radar horizon and the ASCM incorporated soft kill measures. Under these circumstances, only "speed greater than M1.0" breaks out with a greater than ten percent

difference in the probability of success – again only in the case where the engagement was limited by the radar horizon and soft kill enhancements by the ASCM side are present.

CHARACTERISTIC	ASCM SURVIVABILITY		with Soft-Kill	
	P_S	P_S - R_h	P_S	P_S - R_h
A: SEA LAUNCHED		(Count = 12)		
AVERAGE:	0.0%	1.2%	1.6%	6.5%
STDEV:	0.00	0.03	0.02	0.10
B: SUB LAUNCHED		(Count = 4)		
AVERAGE:	0.0%	0.4%	1.4%	11.4%
STDEV:	0.00	0.01	0.03	0.14
LAND LAUNCHED		(Count = 5)		
AVERAGE:	0.0%	0.5%	0.3%	8.9%
STDEV:	0.00	0.01	0.00	0.15
AIR LAUNCHED		(Count =7)		
AVERAGE:	0.0%	2.0%	0.9%	7.1%
STDEV:	0.00	0.03	0.02	0.13
SPEED < M1.0		(Count = 15)		
AVERAGE:	0.0%	0.2%	0.1%	2.3%
STDEV:	0.00	0.00	0.00	0.00
SPEED >=M1.0		(Count = 4)		
AVERAGE:	0.1%	3.0%	4.2%	13.3%
STDEV:	0.00	0.05	0.02	0.15
DIAMETER < 40 cm		(Count = 10)		
AVERAGE:	0.0%	0.2%	0.1%	2.4%
STDEV:	0.00	0.00	0.00	0.02
40 cm < DIAMETER 100 cm		(Count = 8)		
AVERAGE:	0.0%	1.5%	1.4%	6.5%
STDEV:	0.00	0.03	0.02	0.12
DIAMETER > 100 cm		(Count = 1)		
AVERAGE:	0.2%	1.0%	5.4%	12.6%
STDEV:				
RADAR HORIZON < 30 km		(Count = 15)		
AVERAGE:	0.0%	0.9%	0.8%	5.0%
STDEV:	0.00	0.02	0.02	0.09
RADAR HORIZON > 30 km		(Count = 4)		
AVERAGE:	0.1%	0.3%	1.4%	3.3%
STDEV:	0.00	0.01	0.03	0.06

Table 16. Summary of time-line survivability comparisons.

2. Monte Carlo Analysis

The Monte Carlo analysis provides a statistical response to the question of how successful would any given ASCM be against a capable target ship. From that data and given assumptions, the ASCM has approximately a ten percent survivability rate with no soft kill measures used which increases to 27–35 percent when soft kill measures are used. Unfortunately for the ASCM, if the ship counters with soft kill measures, the success rates return to the ten percent range, using similarly capable soft kill measures.

There is little correlation noted in the data with respect to the operational scenario. More correlation is noticed with the attack altitude and radar horizon which defines the range the first shot can be taken. At the radar horizon, all targets presented an RCS to the target ship that easily allowed detection followed by a high number of shots. This is due to the assumed highly capable acquisition radar on the target ship. If the target ship were assumed to be less capable, the ASCM could have a corresponding higher probability of success.

Table 17 summarizes the comparisons made using the Monte Carlo analysis. Comparisons were made for the number of shots possible against the ASCM, operational scenario, speed, size (RCS), and radar horizon. In this data, none of the groups showed any significant variations from the overall averages. The one outlier is the M3.0 Sunburn 3M-80E that only receives one missile shot and the CIWS used against it. A closer look at the data showed that Sunburn 3M-80 is the only ASCM with n (N in the model) equal to one. Table 18 shows the Monte Carlo results for n=1 and n=5. When $n = 5$, the values are closely aligned with the other ASCMs and Sunburn is no longer an outlier. The value $n = 1$ in the binomial distribution did not let the model fluctuate enough to get realistic values. Therefore, future analysis will need to use the higher value of n. Note that this one ASCM result skewed the results for three cases, the N<4, speed >M1.0, and size greater than 100 cm categories.

Table 19 shows a comparison of the straight multiplication from the time line analysis from the single shot that was taken after the radar horizon and the mean results from the Monte Carlo results. The green shading and green font in the Monte Carlo

results depicts that the numbers matched within ten percent for the no soft kill case and within twelve percent of the case with soft kill measures added. Again the data matches very closely except in the cases where low values of *n* were used.

CHARACTERISTIC		ASCM ONLY				ASCM + ASCM SK				ASCM + ASCM SK + SHIP SK			
	SRSAM N	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev
OVERALL	(Count = 19)												
AVERAGE:	4.32	0.00%	74.56%	9.79%	0.1548	27.93%	79.00%	35.13%	0.1066	0.30%	73.66%	11.62%	0.1441
STDEV:	1.60	0.00%	14.73%	0.08%	0.0454	1.43%	13.54%	2.33%	0.0334	0.00%	15.32%	1.58%	0.0310
N<4	(Count = 4)												
AVERAGE:	1.75	0.00%	100.00%	9.81%	0.2305	27.33%	70.36%	32.89%	0.1171	0.30%	99.69%	9.91%	0.1990
STDEV:	0.50	0.00%	0.00%	0.09%	0.0447	0.00%	28.69%	3.71%	0.0781	0.00%	0.25%	2.77%	0.0065
N=4	(Count = 5)												
AVERAGE:	4.00	0.00%	72.50%	9.76%	0.1474	29.62%	85.51%	37.12%	0.1142	0.30%	73.43%	12.10%	0.1426
STDEV:	-	0.00%	5.59%	0.05%	0.0025	2.10%	5.17%	2.00%	0.0033	0.00%	6.69%	0.68%	0.0024
N=5	(Count = 6)												
AVERAGE:	5.00	0.00%	65.83%	9.79%	0.1338	27.33%	80.88%	35.01%	0.1030	0.30%	66.02%	12.32%	0.1281
STDEV:	-	0.00%	7.65%	0.07%	0.0063	0.00%	4.56%	0.05%	0.0008	0.00%	3.00%	0.72%	0.0015
N>5	(Count = 4)												
AVERAGE:	6.25	0.00%	64.80%	9.83%	0.1196	27.33%	76.68%	35.06%	0.0919	0.30%	59.36%	11.69%	0.1150
STDEV:	0.50	0.00%	3.74%	0.11%	0.0056	0.00%	4.69%	0.09%	0.0029	0.00%	6.43%	0.69%	0.0060
A: Sea Launched	(Count = 12)												
AVERAGE:	3.83	0.00%	78.49%	9.79%	0.1667	27.96%	78.51%	34.90%	0.1087	0.30%	77.48%	11.39%	0.1536
STDEV:	1.70	0.00%	16.79%	0.06%	0.0532	1.49%	16.97%	2.78%	0.0419	0.00%	17.57%	1.90%	0.0348
B: Submarine Launched	(Count = 4)												
AVERAGE:	3.25	0.00%	83.75%	9.76%	0.1956	27.33%	69.72%	32.99%	0.0905	0.30%	82.44%	10.65%	0.1623
STDEV:	2.06	0.00%	19.74%	0.04%	0.0755	0.00%	28.35%	3.78%	0.0654	0.00%	19.92%	3.34%	0.0401
C: Land Launched	(Count = 5)												
AVERAGE:	4.60	0.00%	69.14%	9.84%	0.1452	28.09%	82.66%	35.71%	0.1125	0.30%	70.70%	11.72%	0.1413
STDEV:	2.06	0.00%	19.74%	0.04%	0.0755	0.00%	28.35%	3.78%	0.0654	0.00%	19.92%	3.34%	0.0401
D: Air Launched	(Count =7)												
AVERAGE:	3.86	0.00%	77.02%	9.76%	0.1588	28.42%	82.56%	35.93%	0.1216	0.30%	78.49%	11.82%	0.1532
STDEV:	1.46	0.00%	16.69%	0.05%	0.0351	1.87%	5.87%	1.81%	0.0248	0.00%	15.04%	0.69%	0.0350
Speed< M 1.0	(Count = 15)												
AVERAGE:	5.00	0.00%	67.78%	9.79%	0.1346	28.09%	81.30%	35.73%	0.1038	0.30%	66.72%	12.08%	0.1294
STDEV:	0.93	0.00%	6.71%	0.08%	0.0121	1.58%	5.68%	1.48%	0.0092	0.00%	7.53%	0.70%	0.0115
Speed>= M 1.0	(Count = 4)												
AVERAGE:	1.75	0.00%	100.00%	9.81%	0.2305	27.33%	70.36%	32.89%	0.1171	0.30%	99.69%	9.91%	0.1990
STDEV:	0.50	0.00%	0.00%	0.09%	0.0447	0.00%	28.69%	3.71%	0.0781	0.00%	0.25%	2.77%	0.0065
Diameter < 40cm	(Count = 10)												
AVERAGE:	4.90	0.00%	69.33%	9.76%	0.1362	27.71%	80.62%	35.35%	0.1048	0.30%	67.69%	12.09%	0.1306
STDEV:	0.74	0.00%	6.58%	0.06%	0.0112	1.21%	4.69%	1.13%	0.0084	0.00%	5.47%	0.75%	0.0093
40 cm < Diameter < 10	(Count = 8)												
AVERAGE:	4.00	0.00%	77.92%	9.83%	0.1601	28.28%	83.42%	35.83%	0.1221	0.30%	77.82%	11.77%	0.1553
STDEV:	1.93	0.00%	18.93%	0.09%	0.0413	1.77%	5.95%	1.72%	0.0294	0.00%	19.89%	0.63%	0.0407
Diameter > 100 cm	(Count = 1)												
AVERAGE:	1.00	0.00%	100.00%	9.80%	0.2975	27.33%	27.33%	27.32%	-	0.30%	99.96%	5.76%	0.1895
STDEV:	-	-	-	-	-	-	-	-	-	-	-	-	-
RH < 30 km	(Count = 15)												
AVERAGE:	4.20	0.00%	75.12%	9.77%	0.1518	28.09%	83.04%	35.65%	0.1161	0.30%	74.67%	11.96%	0.1462
STDEV:	1.32	0.00%	14.26%	0.06%	0.0307	1.58%	4.80%	1.52%	0.0219	0.00%	14.13%	0.72%	0.0303
RH >30 km	(Count = 4)												
AVERAGE:	4.75	0.00%	72.46%	9.88%	0.1660	27.33%	63.82%	33.17%	0.0708	0.30%	69.85%	10.34%	0.1361
STDEV:	2.63	0.00%	18.62%	0.09%	0.0881	0.00%	24.56%	3.90%	0.0476	0.00%	21.26%	3.12%	0.0370

Table 17. Summary of Monte Carlo Averages and Standard Deviations.

Missile	Version	SRSAM N	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev	Minimum P_s	Maximum P_s	Mean P_s	Std Dev
Sunburn (3M-80E)	SSN-22	1	0.000%	100.000%	9.900%	0.29881	27.325%	27.325%	27.325%	-	0.300%	99.987%	8.350%	0.20777
Sunburn (3M-80E)	SSN-22	5	0.000%	68.000%	9.752%	0.13120	27.325%	79.175%	34.987%	0.10230	0.300%	66.711%	12.868%	0.12669

Table 18. Sensitivity to *n* for Sunburn ASCM.

Missile	Version	Multiply Method	Multiply Method with Soft Kill	Monte Carlo Mean P_s	Monte Carlo with Soft Kill Mean P_s
Exocet	MM38	9.78%	35.00%	9.77%	38.57%
Exocet	SM39	9.77%	34.99%	9.84%	38.56%
Exocet	MM40	9.77%	34.99%	9.84%	38.65%
Exocet	AM39	9.77%	34.99%	9.78%	38.61%
Harpoon	RGM-84	9.76%	34.99%	9.77%	38.69%
Harpoon	UGM-84	9.76%	34.99%	9.73%	38.64%
Harpoon	AGM84	14.04%	38.43%	9.82%	38.61%
Silkworm	CSS-C-2	19.46%	42.80%	9.69%	38.49%
Sizzler (91RE2)	SS-N-27	9.76%	34.99%	9.77%	38.51%
Sizzler (3M-14E)	SS-N-27	9.77%	34.99%	9.79%	38.63%
Saccade C-802	CSSC-8/CSS-N-8	9.77%	34.99%	9.75%	38.61%
Saccade C-802	CAS-8	9.77%	34.99%	9.74%	38.61%
Sardine	CSS-C-4	9.88%	35.09%	9.80%	38.56%
Styx	SS-N-2D	9.81%	35.02%	9.84%	38.65%
Sunburn (3M-80E)	SS-N-22	9.75%	34.98%	19.44%	45.97%
Sunburn (Kh-41)	SS-N-22	9.76%	34.98%	9.93%	38.73%
Switchblade	SS-N-25	9.76%	37.94%	9.80%	38.56%
BrahMos	PJ-10	9.77%	34.99%	14.03%	41.88%
RBS-15 Mk 2	RBS-15	9.77%	34.99%	9.73%	38.60%

Table 19. Comparison between Monte Carlo and straight multiply results.

IV. APPLICATION OF STUDY AND CONCLUSION

A. APPLICATION

Decision tree and time line analysis are straightforward tools that can be implemented on standard desktop computers. These tools were used in this study to investigate the effects of ASCM performance while attempting to target and destroy a capable target ship equipped with modern sensors and defensive weapons systems. The tools used here were able to quickly provide insight into the problems the ASCM faces which in turn reveals features that a target ship can capitalize on. For example, high speed was shown to directly reduce the opportunity of a target ship to defend against the ASCM since high speed translates to short visibility windows and less time to employ defensive measures. Even given the same probability of kill statistics, the high speed missile provides a higher threat to the target ship, because, at a minimum, it has to be prioritized at the highest level because any delay in deciding to defend against the ASCM leaves even less time to counter it. When employed with soft kill measures, the higher speed ASCMs showed the highest potential to get through the target ship defenses.

Ball (2003) suggests the following characteristics will affect the kill chain in the following ways:

Susceptibility Factors:

1. Threat Avoidance
    - Hide Launch – launch outside the target ship's detection envelope
2. Detection Avoidance
    - Keep ASCM profile under radar horizon as long as possible
    - Low RCS – delays detection
3. Engagement Avoidance
    - Remain under radar horizon as long as possible – target detection delay reduces time to react

- Speed – faster time through envelope reduces time to react
- Maneuver – guidance commands require constant vigilance to maintain attack
- Electronic Jamming – obscuration of target reduces time to react and tracking confidence
- Decoy – seduces proliferators, but not realistic on an ASCM
- Low RCS – reduces threat systems capability to counter threat

4. Threat or Hit Avoidance
    - Speed/Maneuver
    - Low RCS

These features are all considered in the simulations used here. Threat avoidance is key to both sides of an ASCM-SAM engagement. Without knowledge that a threat is imminent, no kill chain defenses are activated. The decision tree assumed that ship readiness was always 100 percent, otherwise the rest of the problem does not matter – the battle is lost from the beginning.

Detection avoidance also occurs on both sides. This study only looked at the ASCM's detection avoidance or reduction techniques, but today's ship planners are already taking this into account ship signature reduction. The ASCM needs to detect the ship before the target ship can target it. Because of the advanced radar technology available in today's ship radar systems, the target ship has a high probability if detecting the incoming ASCM, despite its relatively small size. There was not much difference seen in the detection probabilities for the sampled ASCMs, but future ASCMs could benefit by RCS reduction of at least one order of magnitude. The radar horizon also played a key role in this study as the ASCMs with very low attack altitudes showed very short radar horizon ranges, leading to fewer attempts by the target ship to defeat the incoming ASCM. Hence ASCM's ability to fly closer to the ground greatly improved performance. This feature could be offset however, by the target ship having over-the-horizon targeting assets to target and engage the ASCM at greater ranges.

Engagement avoidance has similar characteristics as detection avoidance. The ASCM needs to be trackable by the target ship for it to engage its weapon system. If the ASCM can remain under radar horizon for as long as possible, the target ship will be delayed in targeting and engaging it. Similarly, high ASCM speed can greatly reduce the time that the ASCM is in the target ship's engagement window, thereby reducing time for the target ship to obtain a target solution and engage the ASCM. Soft kill measures from the ASCM-side forces can assist in obscuring the ASCM and confusing the target ship, thereby delaying the target ship's ability to defend against the ASCM. One thing not looked at in this study that can affect the engagement phase is ASCM maneuvers. It is more difficult for the target ship to track a maneuvering target because the target solution is constantly changing every time the target (ASCM) maneuvers.

The kill given a hit (kill/hit) phase may also be affected by avoidance techniques. If the intercept can be broken at the last minute and a hit avoided, the ASCM has a chance to complete its mission. However, similar techniques used in other phases to avoid detection, employ speed, maneuver, employ soft kill features are not expected to be to get the results achieved in those phases. Physical improvements such as hardening the ASCM may be shown to be more effective.

B. CONCLUSIONS

1. Key Points and Recommendations

The research question was "What can ship designer's do to improve survivability against anti-ship cruise missiles? What ASCM features can be exploited to enhance the ability to attack them before they reach their target? How can common software tools such as decision tree models and spreadsheets be used to help analyze this scenario?"

This paper shows that common software programs that perform spreadsheet and decision tree analysis can be used to provide insight to the ship designer. The study showed that an ASCM designer is likely to increase speed, fly low, and reduce RCS to improve its chances. Additionally, they are highly likely to employ soft kill measures such as jamming as ways to improve results with current systems.

The mirror images of these findings are that the defending ship's survivability can be enhanced by exploiting selected features of potential missiles, namely, slower speeds, larger radar cross sections, higher attack profiles, and jamming countermeasures.

Today's radar systems are highly capable and may not need to be improved to produce detection results desired. They may however, need to employ features that counter soft kill measures and need high reliability to be ready at all times.

2. Areas for Further Research

The decision tree analysis can easily be enhanced to include more features that affect the kill chain. For example, the soft kill analysis could be expanded by more detailed modeling of actual real life detection and tracking effects like ground clutter, multiple targets, and radio wave ducting. Future studies should look at multiplicative effects such as the addition of more target ships and the addition of multiple ASCMs. Additionally, the effect of saturating a single target ship with ASCMs from multiple angles should be researched. Including maneuvering ASCMs into the model should also be considered.

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APPENDIX. DATA ANALYSIS RESULTS

ASCM / Characteristic[1]	Exocet				RBS-15 Mk2			SILKWORM
	MM 38 (ship)	MM 40 (ship)	SM 39 (Sub)	AM 39 (Air)	RBS-15F	RBS-15K	RBS-15L	CSS-C-2/HY-1/SY-1
Origin	France	France	France	France	*Sweden*	*Sweden*	*Sweden*	China
Weight (kg)	670 - 735 kg				630 kg	800 kg	80 kg	2,300 kg
	1500 - 1620 lb				1771 lbs	1771 lbs	1771 lbs	5060 lbs
length (m)	5.21 m	5.8 m	4.69 m	4.69 m	4.35 m	4.35 m	4.35 m	6.6m
	17.1 ft	19.0 ft	15.4 ft	15.4 ft				
diameter (cm)	35 cm	35 cm	35 cm	35 cm	50 cm	50 cm	50 cm	76 cm
	13.8 in	13.8 in	13.8 in	13.8 in	19.7 in	19.7 in	19.7 in	
Wingspan								2.4m
warhead	165 kg HE	165 kg HE	165 kg HE	165 kg HE	200 kg HE SAP	200 kg HE SAP	200 kg HE SAP	454 kg he
	363.8 lbs	363.8 lbs	363.8 lbs	363.8 lbs	441 lb HE	441 lb HE	441 lb HE	
Engine	Solid	Solid	Solid	Solid	Turbojet	Turbojet	Turbojet	
Min Range					10 km	10 km	10 km	
Operational Range	40 km	70 km	50 km	70 km	150 km	150 km	150 km	40 km
	21.6 nm	37.8 nm	30.0 nm	37.8 nm	108 nmi	108 nmi	108 nmi	
Attack Altitude	3m[5]	3m[5]	3m[5]	3m[5]	3m	3m	3m	30 m
Cruise Altitude								100-300m
Speed	1134 km/h	1134 km/h	1134 km/h	1134 km/h				
	612 kts	612 kts	612 kts	612 kts				
	M .9	M .9	M .9	M .9	M .8	M .8	M .8	M.9
Navigation	Inertial	Inertial	Inertial	Inertial	Inertial, GPS	Inertial, GPS	Inertial, GPS	
Terminal guidance	Active Radar	Active Radar	Active Radar	Active Radar	Active Radar (J-Band)	Active Radar (J-Band)	Active Radar (J-Band)	
Surface Ship [A]	Yes	Yes					Yes	Yes
Sub-Surface [B]			Yes					
Land [C]						Yes	Yes	Yes
Air [D]				Yes	Yes			

[1] Information extracted from Jane's Strategic Weapon System's at www.janes.com unless otherwise noted
[2] Information extracted from Global Security.org
[3] Information extracted from FAS.org
[4] Information extracted from Mahnken (2005)
[5] Estimate of 3m used where "sea skimming" is reported

Table 20. Typical Anti-Ship Cruise Missile (ASCM) profiles (1/3).

ASCM / Characteristic[1]	3M-54 Klub / SS-N-27 / SIZZLER[3]					Saccade C-802		Sardine	Styx	
	3M-54E	3M-54E1	3M-14E	91RE1	91RE2	CSSC-8/SS-N-8	CAS-8	CSS-N-4	SS-N-2c	SS-N-2d
Origin	China	China	China	China	China	China	China	Rusia	Russia	Russia
Weight (kg)	2300 kg	1780 kg	1780 kg	2050 kg	1300 kg	715 kg [A,C]	555 kg [D]	815 kg	2500 kg	2600 kg
	5060 lbs	3916 lbs	3916 lbs	4510 lbs	2860 lbs				5500 lbs	5720 lbs
length (m)	8.22 m	6.2 m	6.2 m	8 m	6.5 m	6.39 m [A,C]	5.3 m [D]	5.81 m	6.5 m	6.5 m
diameter (cm)	53.3 cm	53.3 cm	53.3 cm	53.3 cm	53.3 cm	36 cm	36 cm	36 cm	76cm	76cm
	21 in	21 in	21 in	21 in	21 in	14.2 in	14.2 in	14.2 in		
Wingspan								1.18 m		
warhead						165 kg HE	165 kg HE			
	200 kg HE	400 kg HE	400 kg HE	76 kg HE	76 kg HE	364 lb HE	364 lb HE	165 kg HE		
Engine						turbo jet	turbo jet	Solid		
Min Range						15 km	15 km	8 km	8 km	8 km
								4.5 nm	3nm	3nm
Operational Range	220 km	300 km	300 km	50 km	40 km	120 km	130 km	42 km	80 km	80 km
	119 km	162 nm	162 nm	27 nm	21.6 km	64.8	70.2	23 nm	43.2 nm	43.2 nm
Attack Altitude	5 -10 m	5 -10 m	5 -10 m	5 -10 m	5 -10 m	5-7 m	5-7 m	20-30 m	25-50 m	25-50 m
Cruise Altitude						20-30 m	20-30 m	50 m		
Speed										
	M .8	M .8	M .9	M 2.5	M 2.0	M .85	M .85	M .9	M .9	M .9
Navigation						Inertial/actice Radar	Inertial/actice Radar			
Terminal guidance								75%		
Surface Ship [A]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub-Surface [B]						Yes	Yes	Yes		
Land [C]						Yes	Yes			
Air [D]						Yes	Yes			

[1] Information extracted from Jane's Strategic Weapon System's at www.janes.com
[2] Information extracted from Global Security.org
[3] Information extracted from FAS.org
[4] Information extracted from Mahnken (2005)
[5] Estimate of 3m used from report of "sea skimming"

Table 21. Typical ASCM profiles (2/3).

ASCM	SSN-22 Sunburn[1,2]				SS-N-25 Switchblade	BrahMos	Harpoon
Characteristic[1]	**3M-80**	**3M-82**	**3M-882M**	**Kh-41**	**Kh-35/SS-N-25/AS-20**	**PJ-10**	**RGM-84**
Origin	Russia	Russia	Russia	Russia	Russia	India	U.S.
Weight (kg)	3970 kg	4150 kg	4150 kg	3950kg	520-610 kg	3900 kg	519-628 kg
					1150 - 1340 lb	8580 lbs	1144-1385 lb
length (m)	9.745 m	9.745 m	9.745 m	9.745 m	3.85 - 5.40 m	9.00 m	4.7m
					12.7 - 14.4 ft		15.4 ft
diameter (cm)	130	130	130	76	42 cm	67 cm	34.3 cm
					1.4 ft	26.4 in	1.1 ft
Wingspan	1.9 m	2.1 m	2.1 m				.91 m
warhead	325 kg HE	325 kg HE	325 kg HE	300kg HE	145 kg HE		221 kg HE
					320 lb HE	200 kg HE	487 lb HE
Engine					turbofan	Ramjet	turbojet
Min Range	10 km	10 km	10 km	10 km			
Operational Range	93 km	120 km	120 km	250 km	130 km	290 km	220 km
	45 nm	65 nm	65 nm		70 nmi	162 nm	
Attack Altitude	20 m	7m	7m	7m	2 m	5 m	3m[5]
Cruise Altitude	20 m	7-20m	7-20m	7-20m	5 m		
Speed					Mach .8		864 km/h
							537 mph
	M2.6	M3	M3	M 2.1		M 2.0	Mach .81
Navigation					inertial, radalt		Inertial, gps
Terminal guidance					active radar		Active Radar
Surface Ship [A]	Yes	Yes	Yes	Yes	Yes	Yes	Yes (RGM-84)
Sub-Surface [B]						Yes	Yes (UGM-84)
Land [C]					Yes (SSC-6)	Yes	
Air [D]				Yes (potential)	Yes (fixed and rotary)	Yes	Yes (AGM-84)

1 Information extracted from Jane's Strategic Weapon System's at www.janes.com unless otherwise noted
2 Information extracted from Global Security.org
3 Information extracted from FAS.org
4 Information extracted from Mahnken (2005)
5 Estimate of 3m used from report of "sea skimming"

Table 22. Typical ASCM profiles (3/3).

P_f=	1.0E-08	PF
P_d(Reference)=	0.90	Pd_ref
CNR for given Pd	22.4 dB	=10*LOG10((LOG10(PF)/LOG10(Pd_ref))-1)
Ref dia for 1 SM target	112.8 cm	2*(SQRT(1/(PI()*10^(rho/10)))*100)
rho	- dB	rho
Mach to km/h @ Sea Level	1223	

RCS Ratio =20*LOG(missile diameter/ reference missile diameter). Reference set by missile diameter with 1 square meter RCS

Range 2 Δ = 40*LOG10(range1/range2)
CNR 2 = CNR_1 + Range2_delta
PD2 = =PF^(1/(1+10^(CNR_2/10)))

																RANGE 1 -- RCS Variation				RANGE 2 -- Range Variation			
	Missile	Version	[A] Sea	[B] Sub	[C] Land	[D] Air	Length (m)	Diameter (cm)	h_{ASCM} (m)	$h_{Radar\ mast}$ (m)	Max Range (km)	Speed (Mach)	Speed (km/h)	Horizon (km) [$R_{horizon}$]	Radar Horizon (sec)	Max Range (sec)	Range 1 (km) [Ref]	RCS Ratio (dBsm)	CNR 1 (dB)	PD 1	Range 2 (km) [Pd Table]	Range 2 Δ (dB)	CNR 2 (dB)	PD 2
1	**Exocet**	MM38	X				5.21	35.0	3	17	40	0.9	1,101	24.1	52	131	167.0	(10.2)	12.2	0.3539507	40.0	24.8	37.1	0.9963846
2	**Exocet**	MM40	X				5.80	35.0	3	17	70	0.9	1,101	24.1	150	229	167.0	(10.2)	12.2	0.3539507	70.0	15.1	27.3	0.9666548
5	**Harpoon**	RGM-84	X				3.85	34.3	3	17	140	0.8	991	24.1	421	509	167.0	(10.3)	12.1	0.3399647	140.0	3.1	15.1	0.5774331
9	**Sizzler (91RE2)**	SS-N-27	X				6.50	53.3	5	17	40	2.5	3,058	26.2	16	47	167.0	(6.5)	15.9	0.6295912	40.0	24.8	40.7	0.9984393
10	**Sizzler (3M-14E)**	SS-N-27	X				8.22	53.3	5	17	300	0.9	1,101	26.2	895	981	167.0	(6.5)	15.9	0.6295912	300.0	(10.2)	5.7	0.0203038
11	**C-802 [Ship]**	C-802	X				5.30	36.0	3	17	120	0.9	1,040	24.1	332	416	167.0	(9.9)	12.5	0.3735360	120.0	5.7	18.2	0.7609070
14	**Styx**	SS-N-2	X				6.50	76.0	30	17	100	0.9	1,101	39.6	198	327	167.0	(3.4)	19.0	0.7941279	100.0	8.9	27.9	0.9704813
16	**Sunburn (Kh-41) [A,D]**	SS-N-22	X			X	9.75	76.0	3	17	100	3.0	3,669	24.1	74	98	167.0	(3.4)	19.0	0.7941279	100.0	8.9	27.9	0.9704813
17	**Switchblade**	SS-N-25	X		X	X	3.85	42.0	2	17	130	0.8	978	22.8	394	478	167.0	(8.6)	13.8	0.4800372	130.0	4.4	18.2	0.7584656
19	**RBS-15**	RBS-15	X		X	X	4.35	50.0	9	17	150	0.9	1,101	29.4	395	491	167.0	(7.1)	15.3	0.5921592	150.0	1.9	17.2	0.7085976
15	**Sunburn (3M-80E) [A]**	SS-N-22	X	X			9.75	130.0	20	17	120	3.0	3,669	35.4	83	118	167.0	1.2	23.6	0.9236361	120.0	5.7	29.4	0.9789790
18	**BrahMos**	PJ-10	X	X	X	X	9.00	67.0	5	17	290	2.0	2,446	26.2	388	427	167.0	(4.5)	17.9	0.7441311	290.0	(9.6)	8.3	0.0926814
6	**Harpoon**	UGM-84		X			3.85	34.3	3	17	140	0.8	991	24.1	421	509	167.0	(10.3)	12.1	0.3399647	140.0	3.1	15.1	0.5774331
3	**Exocet**	SM39		X			4.69	35.0	3	17	50	0.9	1,101	24.1	85	164	167.0	(10.2)	12.2	0.3539507	50.0	20.9	33.2	0.9911989
8	**Silkworm**	CSS-C-2			X		6.60	76.0	100	17	100	0.8	978	58.2	154	368	167.0	(3.4)	19.0	0.7941279	100.0	8.9	27.9	0.9704813
13	**Sardine**	CSS-C-4			X		5.81	36.0	30	17	42	0.9	1,101	39.6	8	137	167.0	(9.9)	12.5	0.3735360	42.0	24.0	36.5	0.9958475
4	**Exocet**	AM39				X	4.69	35.0	3	17	70	0.9	1,101	24.1	150	229	167.0	(10.2)	12.2	0.3539507	70.0	15.1	27.3	0.9666548
7	**Harpoon**	AGM84				X	3.85	34.3	3	17	315	0.8	991	24.1	1,057	1,145	167.0	(10.3)	12.1	0.3399647	315.0	(11.0)	1.0	0.0002988
12	**C-802 [Air]**	C-802(CAS-8)				X	6.39	36.0	3	17	130	0.9	1,040	24.1	367	450	167.0	(9.9)	12.5	0.3735360	130.0	4.4	16.8	0.6877970

Table 23. RCS and probability of detection computations for several ASCMs at 167 km and at their maximum range.

P_f=	1.0E-08	PF
P_d(Reference)=	0.90	Pd_ref
CNR for given Pd	22.4	dB =10*LOG10((LOG10(PF)/LOG10(Pd_ref))-1)
Ref dia for 1 SM target	112.8	cm 2*(SQRT(1/(PI()*10^(rho/10)))*100)
rho	-	dB rho
Mach to km/h @ Sea Level	1223	

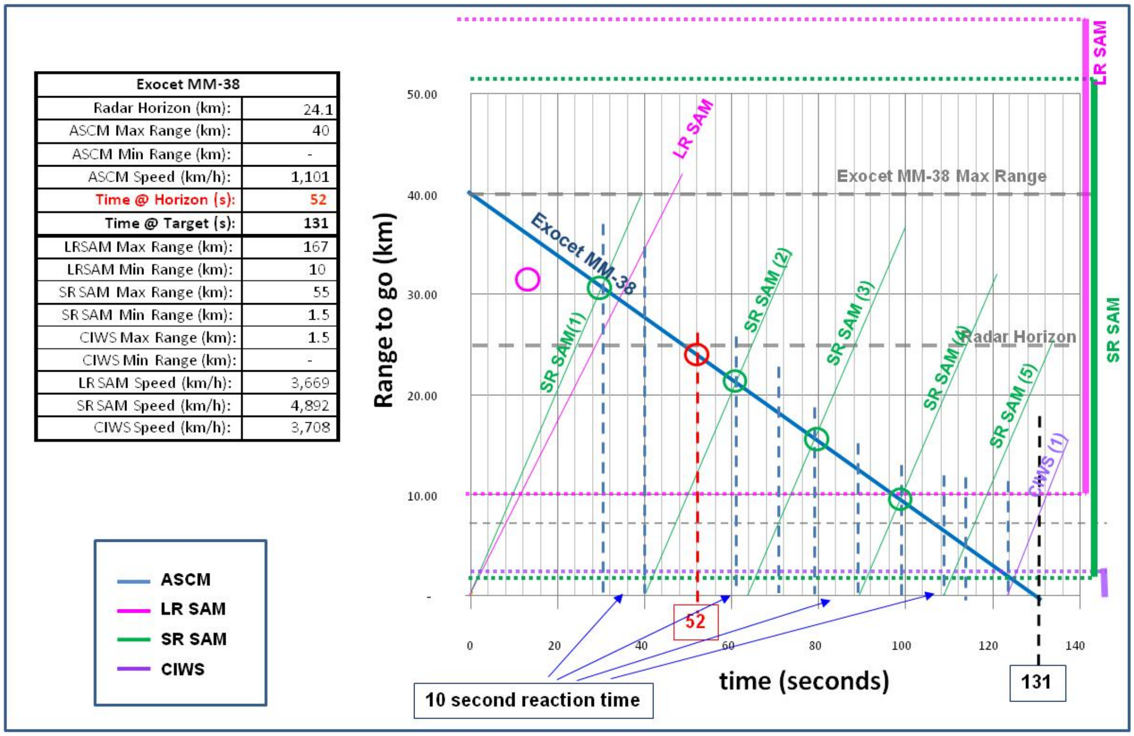
RCS Ratio =20*LOG(missile diameter/ reference missile diameter). Reference set by missile diameter with 1 square meter RCS

Range 2 Δ = 40*LOG10(range1/range2)
CNR 2 = CNR_1+ Range2_delta
PD2= =PF^(1/(1+10^(CNR_2/10)))

																	RANGE 1 -- RCS Variation				RANGE 2 -- Range Variation			
	Missile	Version	[A] Sea	[B] Sub	[C] Land	[D] Air	Length (m)	Diameter (cm)	h_{ASCM} (m)	$h_{Radar\ mast}$ (m)	Max Range (km)	Speed (Mach)	Speed (km/h)	Horizon (km) [$R_{horizon}$]	Radar Horizon (sec)	Max Range (sec)	Range 1 (km) [Ref]	RCS Ratio (dBsm)	CNR 1 (dB)	PD 1	Range 2 (km) [Pd Table]	Range 2 Δ (dB)	CNR 2 (dB)	PD 2
1	**Exocet**	MM38	X				5.21	35.0	3	17	40	0.9	1,101	24.1	52	131	167.0	(10.2)	12.2	0.3539507	24.1	33.6	45.8	0.9995191
2	**Exocet**	MM40	X				5.80	35.0	3	17	70	0.9	1,101	24.1	150	229	167.0	(10.2)	12.2	0.3539507	24.1	33.6	45.8	0.9995191
5	**Harpoon**	RGM-84	X				3.85	34.3	3	17	140	0.8	991	24.1	421	509	167.0	(10.3)	12.1	0.3399647	24.1	33.6	45.7	0.9994992
9	**Sizzler (91RE2)**	SS-N-27	X				6.50	53.3	5	17	40	2.5	3,058	26.2	16	47	167.0	(6.5)	15.9	0.6295912	26.2	32.2	48.0	0.9997114
10	**Sizzler (3M-14E)**	SS-N-27	X				8.22	53.3	5	17	300	0.9	1,101	26.2	895	981	167.0	(6.5)	15.9	0.6295912	26.2	32.2	48.0	0.9997114
11	**C-802 [Ship]**	C-802	X				5.30	36.0	3	17	120	0.9	1,040	24.1	332	416	167.0	(9.9)	12.5	0.3735360	24.1	33.6	46.1	0.9995454
14	**Styx**	SS-N-2	X				6.50	76.0	30	17	100	0.9	1,101	39.6	198	327	167.0	(3.4)	19.0	0.7941279	39.6	25.0	44.0	0.9992629
16	**Sunburn (Kh-41) [A,D]**	SS-N-22	X			X	9.75	76.0	3	17	100	3.0	3,669	24.1	74	98	167.0	(3.4)	19.0	0.7941279	24.1	33.6	52.6	0.9998980
17	**Switchblade**	SS-N-25	X		X	X	3.85	42.0	2	17	130	0.8	978	22.8	394	478	167.0	(8.6)	13.8	0.4800372	22.8	34.6	48.4	0.9997328
19	**RBS-15**	RBS-15	X		X	X	4.35	50.0	9	17	150	0.9	1,101	29.4	395	491	167.0	(7.1)	15.3	0.5921592	29.4	30.2	45.5	0.9994838
15	**Sunburn (3M-80E) [A]**	SS-N-22	X	X			9.75	130.0	20	17	120	3.0	3,669	35.4	83	118	167.0	1.2	23.6	0.9236361	35.4	26.9	50.6	0.9998381
18	**BrahMos**	PJ-10	X	X	X	X	9.00	67.0	5	17	290	2.0	2,446	26.2	388	427	167.0	(4.5)	17.9	0.7441311	26.2	32.2	50.0	0.9998174
6	**Harpoon**	UGM-84		X			3.85	34.3	3	17	140	0.8	991	24.1	421	509	167.0	(10.3)	12.1	0.3399647	24.1	33.6	45.7	0.9994992
3	**Exocet**	SM39		X			4.69	35.0	3	17	50	0.9	1,101	24.1	85	164	167.0	(10.2)	12.2	0.3539507	24.1	33.6	45.8	0.9995191
8	**Silkworm**	CSS-C-2			X		6.60	76.0	100	17	100	0.8	978	58.2	154	368	167.0	(3.4)	19.0	0.7941279	58.2	18.3	37.3	0.9965529
13	**Sardine**	CSS-C-4			X		5.81	36.0	30	17	42	0.9	1,101	39.6	8	137	167.0	(9.9)	12.5	0.3735360	39.6	25.0	37.5	0.9967195
4	**Exocet**	AM39				X	4.69	35.0	3	17	70	0.9	1,101	24.1	150	229	167.0	(10.2)	12.2	0.3539507	24.1	33.6	45.8	0.9995191
7	**Harpoon**	AGM84				X	3.85	34.3	3	17	315	0.8	991	24.1	1,057	1,145	167.0	(10.3)	12.1	0.3399647	24.1	33.6	45.7	0.9994992
12	**C-802 [Air]**	C-802(CAS-8)				X	6.39	36.0	3	17	130	0.9	1,040	24.1	367	450	167.0	(9.9)	12.5	0.3735360	24.1	33.6	46.1	0.9995454

Table 24. RCS and probability of detection computations for several ASCMs at 167 km and at their radar horizon.

EXOCET MM-38



EXOCET SM-39

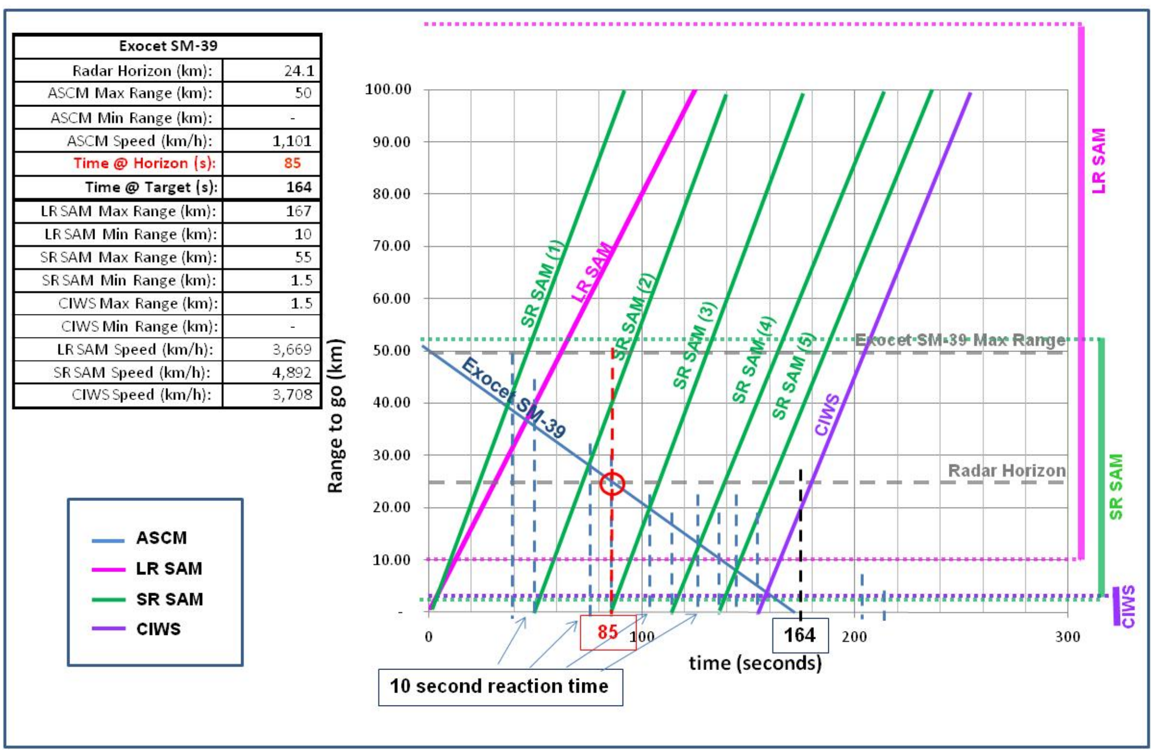
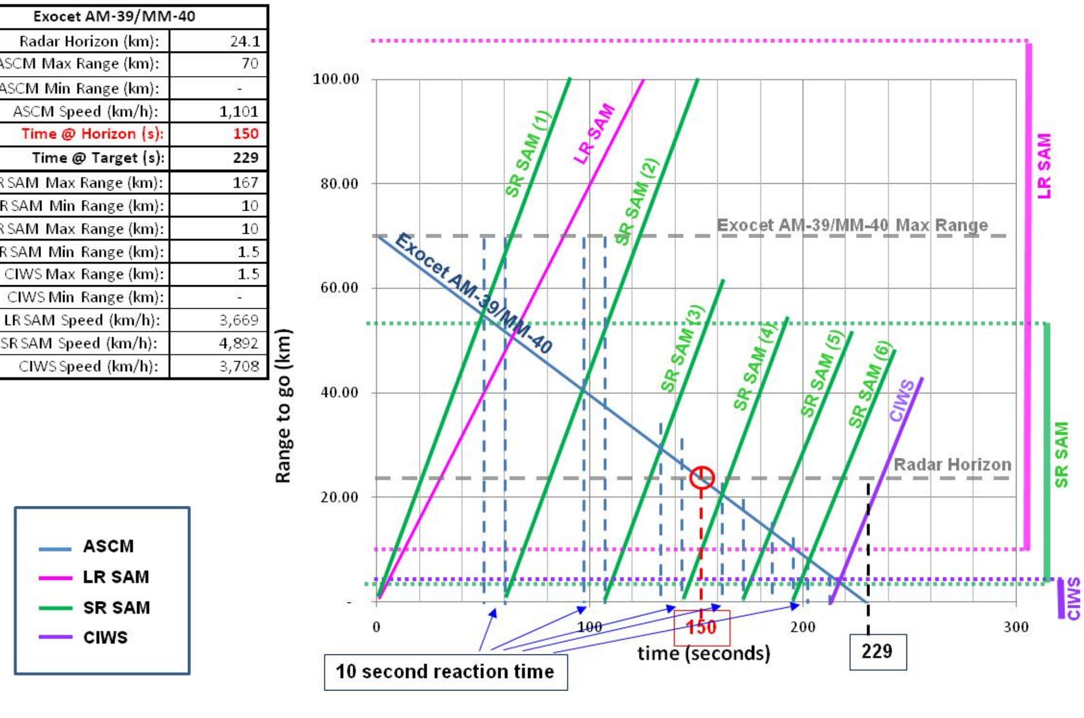


Table 25. ASCM time-line diagrams (1/9).

EXOCET AM-39/MM-40

Exocet AM-39/MM-40	
Radar Horizon (km):	24.1
ASCM Max Range (km):	70
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,101
Time @ Horizon (s):	150
Time @ Target (s):	229
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	10
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708



SILKWORM

Silkworm	
Radar Horizon (km):	58.2
ASCM Max Range (km):	100
ASCM Min Range (km):	-
ASCM Speed (km/h):	978
Time @ Horizon (s):	154
Time @ Target (s):	368
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

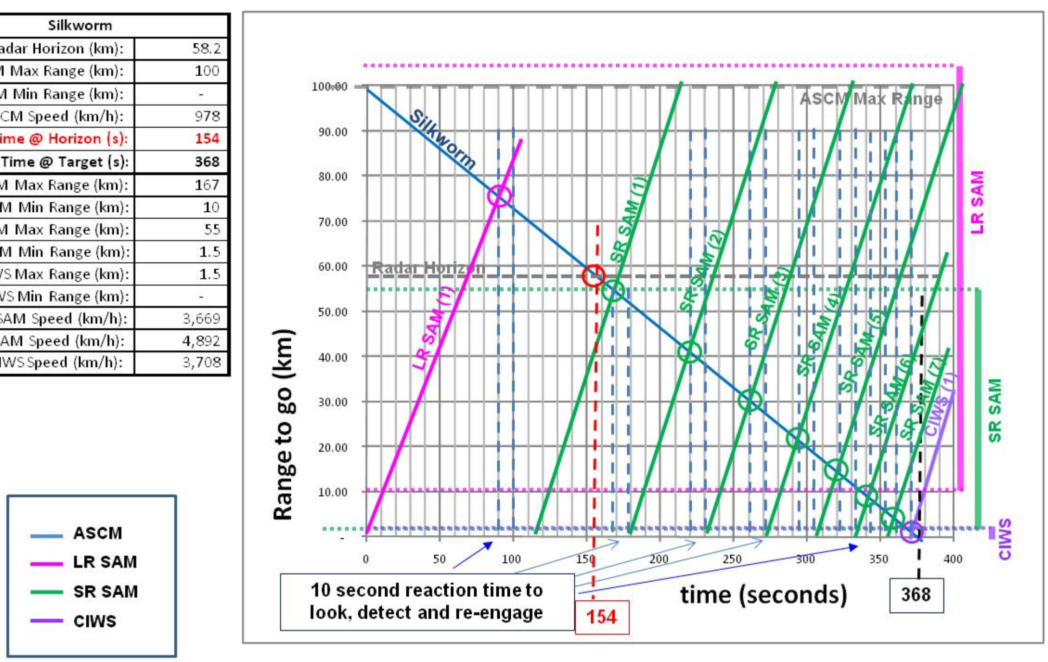
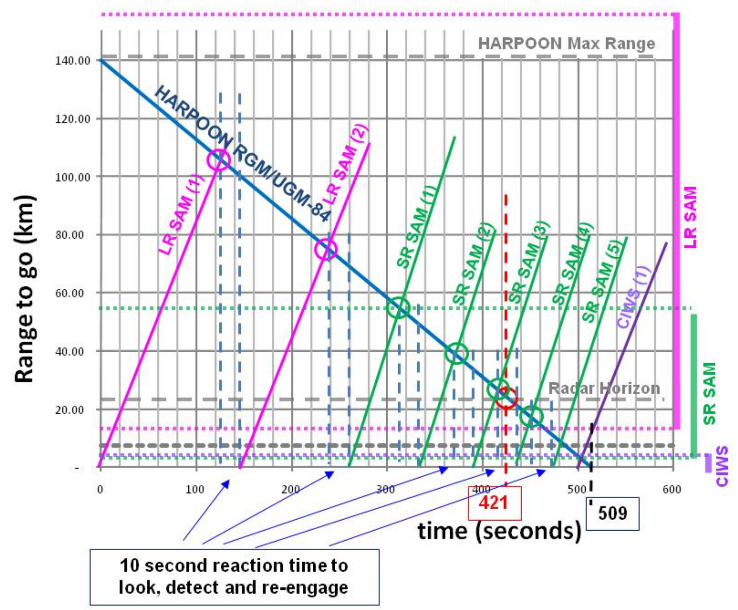


Table 26. ASCM time-line diagrams (2/9).

HARPOON RGM/UGM-84

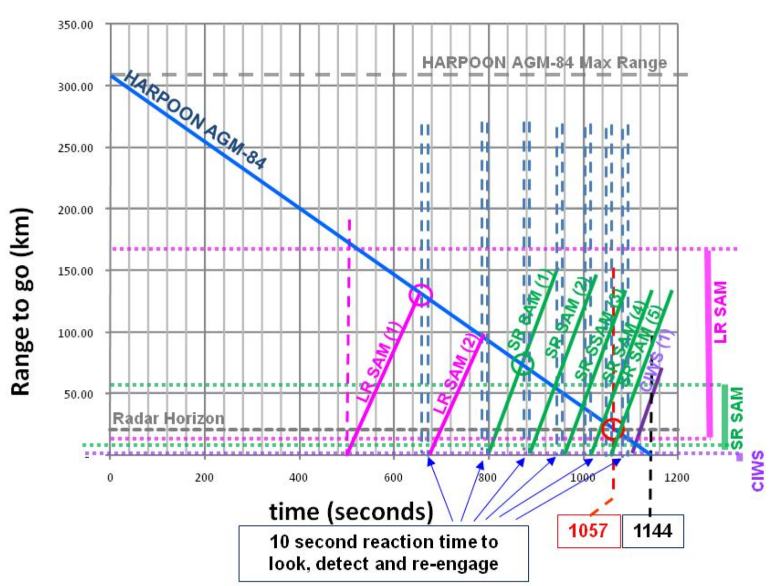
Harpoon RGM/UGM-84	
Radar Horizon (km):	24.1
ASCM Max Range (km):	140
ASCM Min Range (km):	-
ASCM Speed (km/h):	991
Time @ Horizon (s):	421
Time @ Target (s):	509
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708



- ASCM
- LR SAM
- SR SAM
- CIWS

HARPOON AGM-84

Harpoon AGM-84	
Radar Horizon (km):	24.1
ASCM Max Range (km):	315
ASCM Min Range (km):	-
ASCM Speed (km/h):	991
Time @ Horizon (s):	1,057
Time @ Target (s):	1,144
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

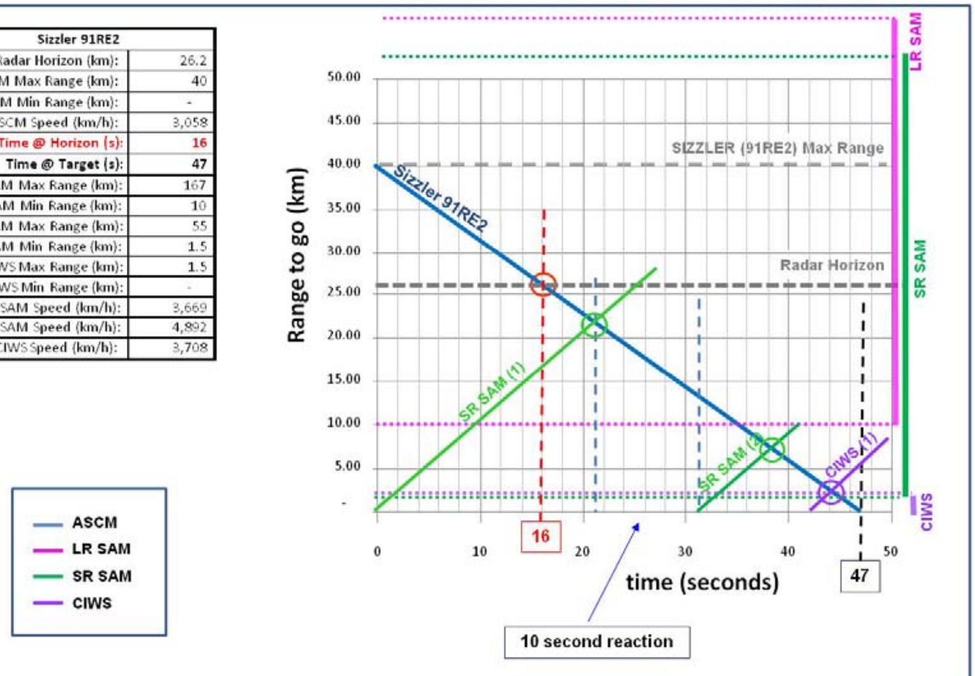


- ASCM
- LR SAM
- SR SAM
- CIWS

Table 27. ASCM time-line diagrams (3/9).

SIZZLER (91RE2)

Sizzler 91RE2	
Radar Horizon (km):	26.2
ASCM Max Range (km):	40
ASCM Min Range (km):	-
ASCM Speed (km/h):	3,058
Time @ Horizon (s):	16
Time @ Target (s):	47
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708



SIZZLER (3M-14E)

Sizzler (3M-14E)	
Radar Horizon (km):	26.2
ASCM Max Range (km):	300
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,101
Time @ Horizon (s):	895
Time @ Target (s):	979
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

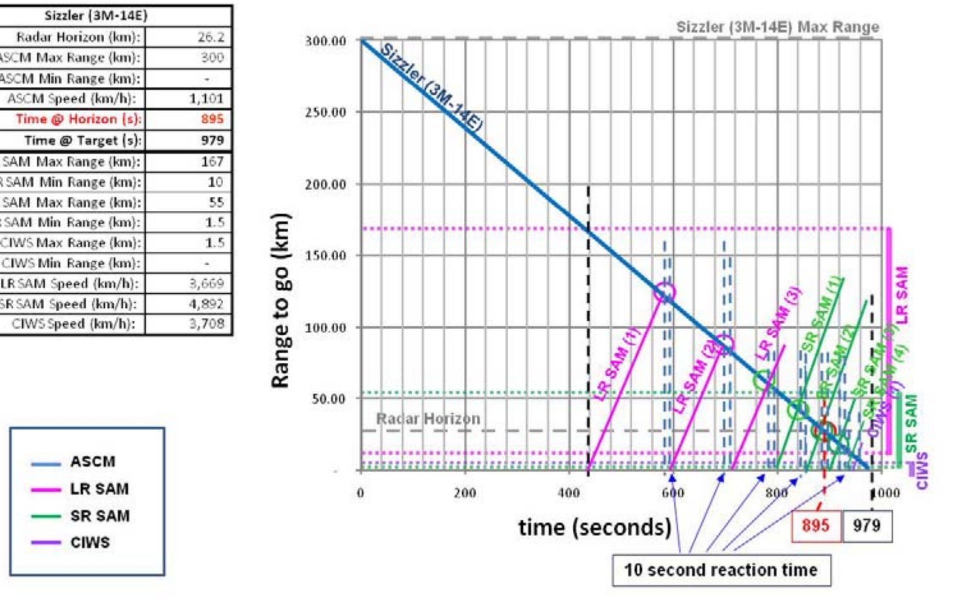
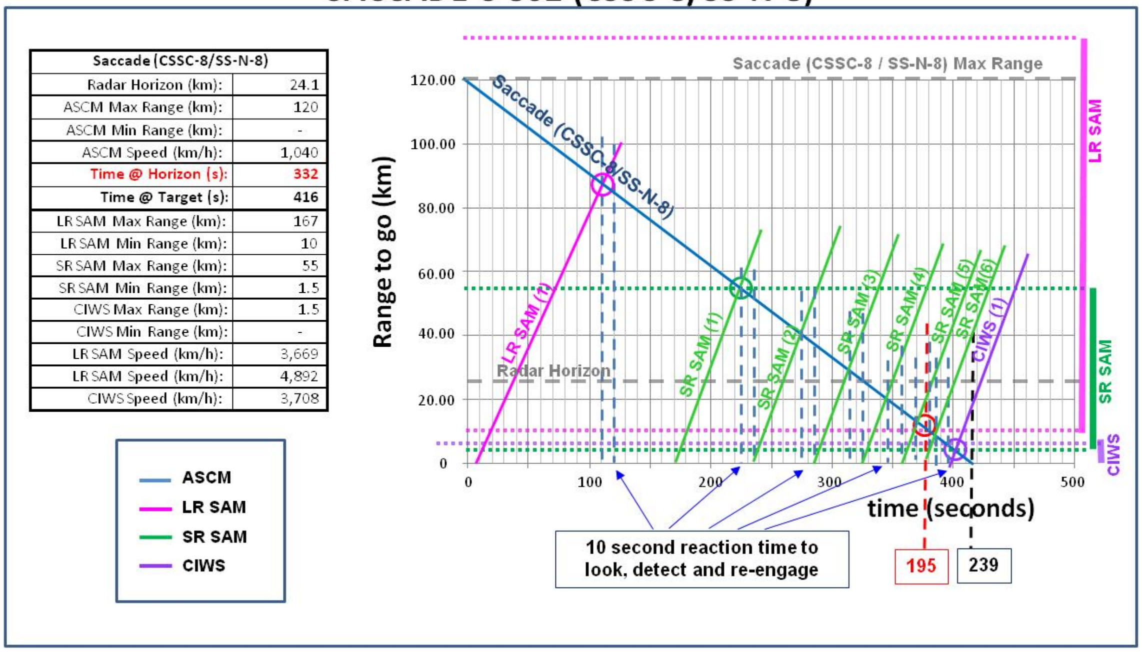


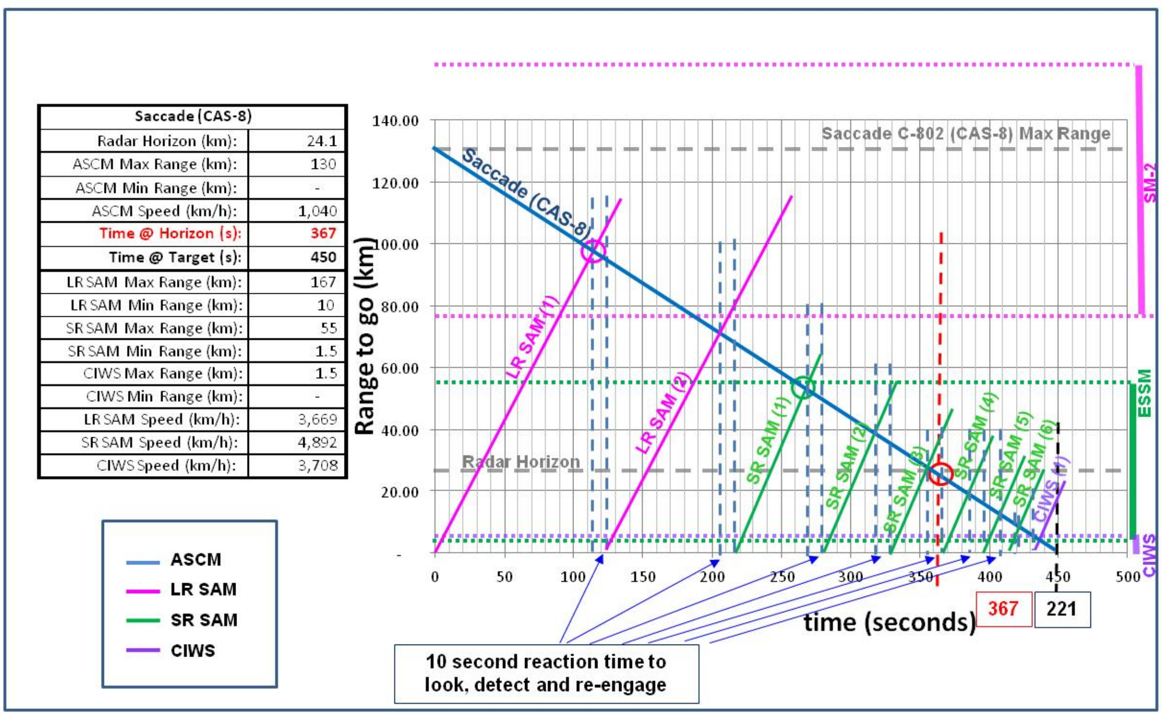
Table 28. ASCM time-line diagrams (4/9).

SACCADE C-802 (CSSC-8/SS-N-8)



Saccade (CSSC-8/SS-N-8)	
Radar Horizon (km):	24.1
ASCM Max Range (km):	120
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,040
Time @ Horizon (s):	332
Time @ Target (s):	416
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
LR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

SACCADE C-802 (CAS-8)

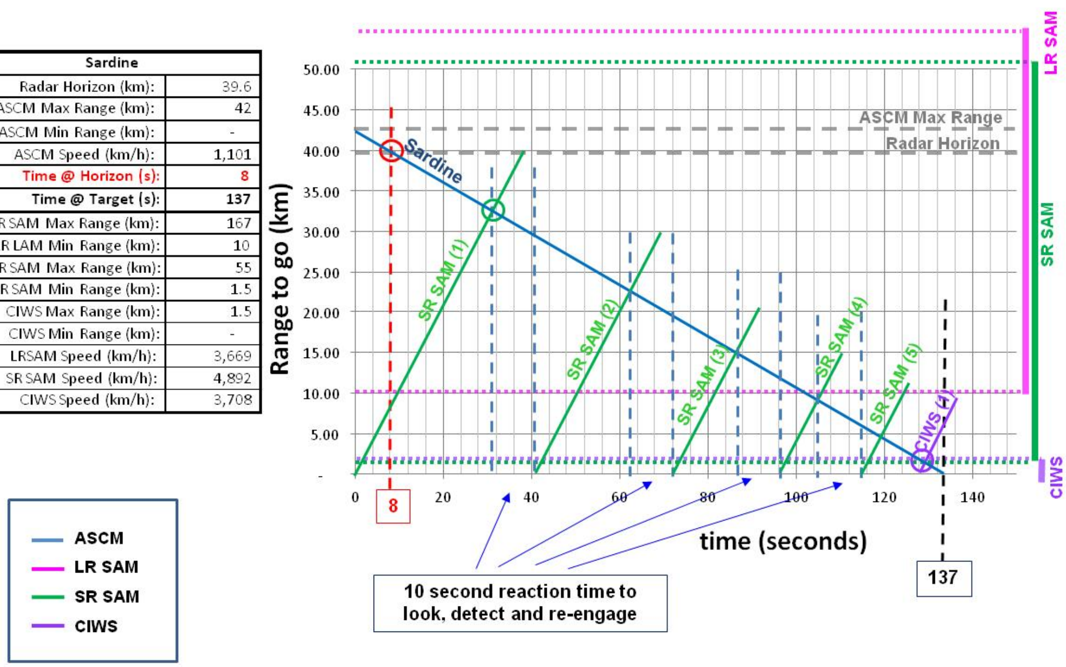


Saccade (CAS-8)	
Radar Horizon (km):	24.1
ASCM Max Range (km):	130
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,040
Time @ Horizon (s):	367
Time @ Target (s):	450
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

Table 29. ASCM time-line diagrams (5/9).

SARDINE

Sardine	
Radar Horizon (km):	39.6
ASCM Max Range (km):	42
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,101
Time @ Horizon (s):	8
Time @ Target (s):	137
LR SAM Max Range (km):	167
LR LAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LRSAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708



STYX

Styx	
Radar Horizon (km):	39.6
ASCM Max Range (km):	100
ASCM Min Range (km):	-
ASCM Speed (km/h):	1,101
Time @ Horizon (s):	198
Time @ Target (s):	326
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

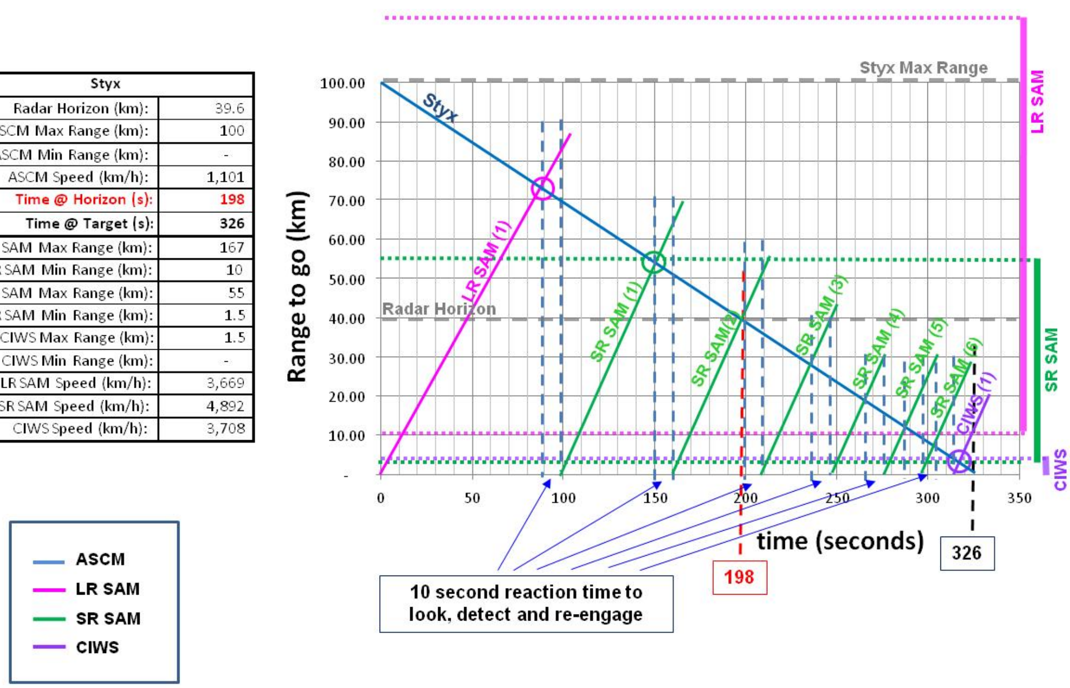
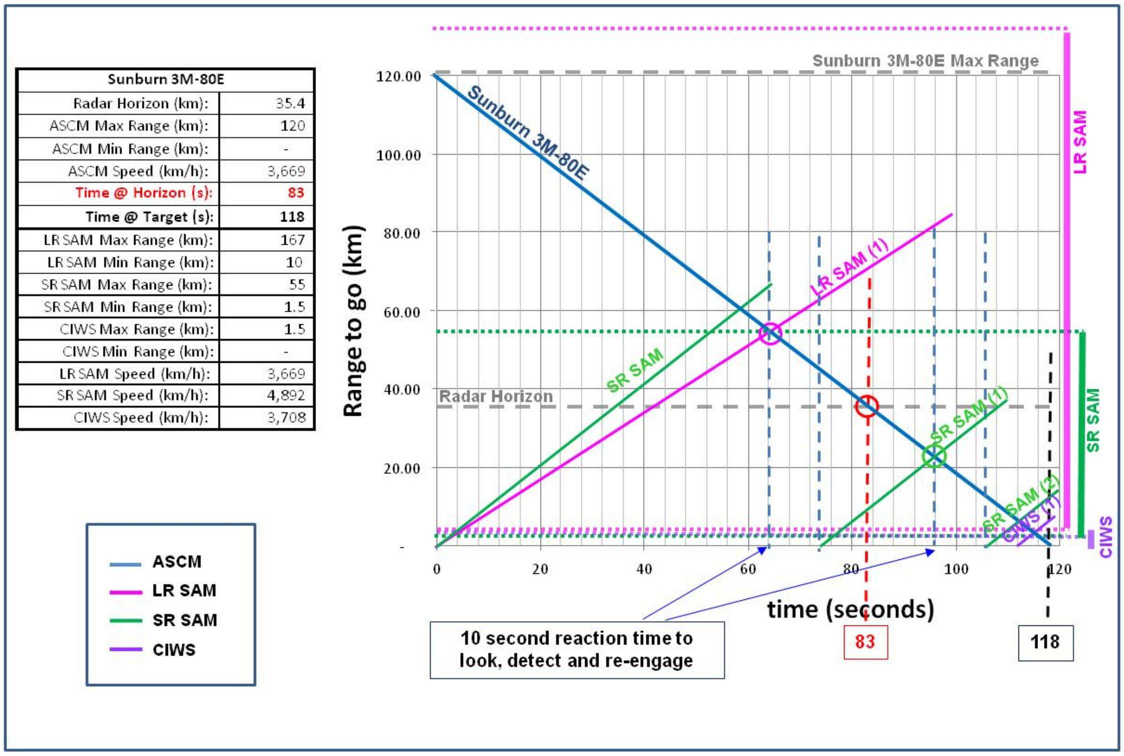


Table 30. ASCM time-line diagrams (6/9).

SUNBURN 3M-80E [A]



SUNBURN Kh-41

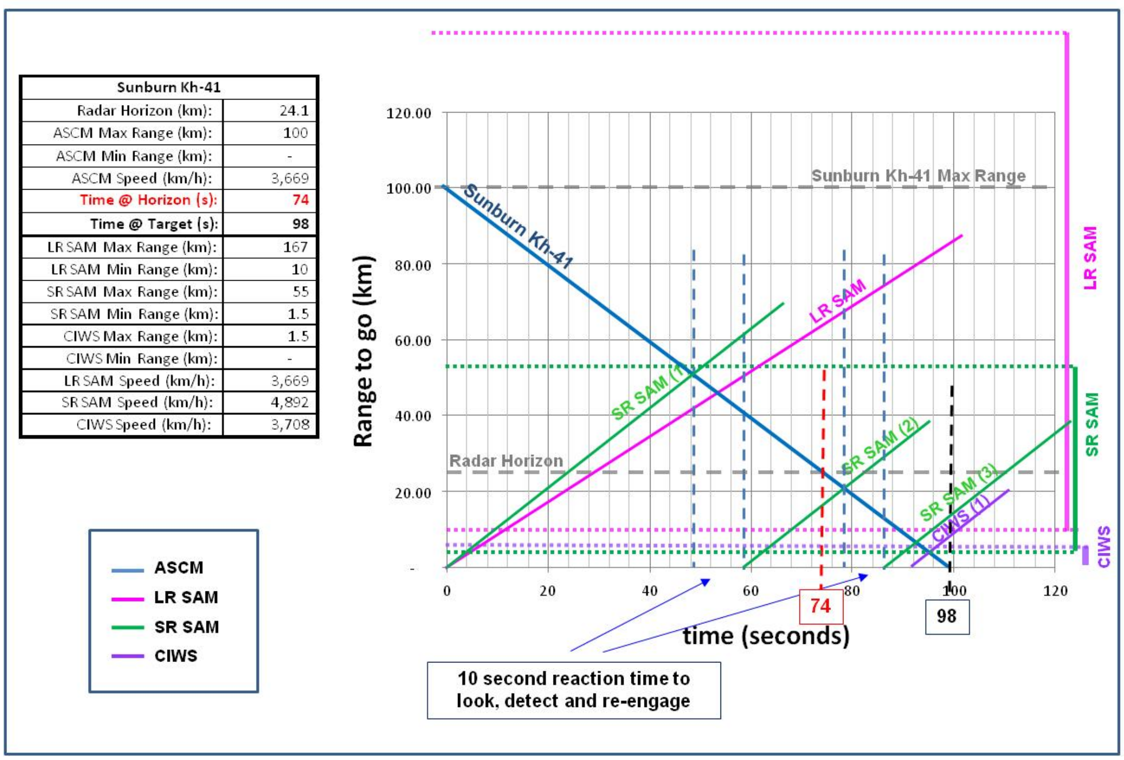
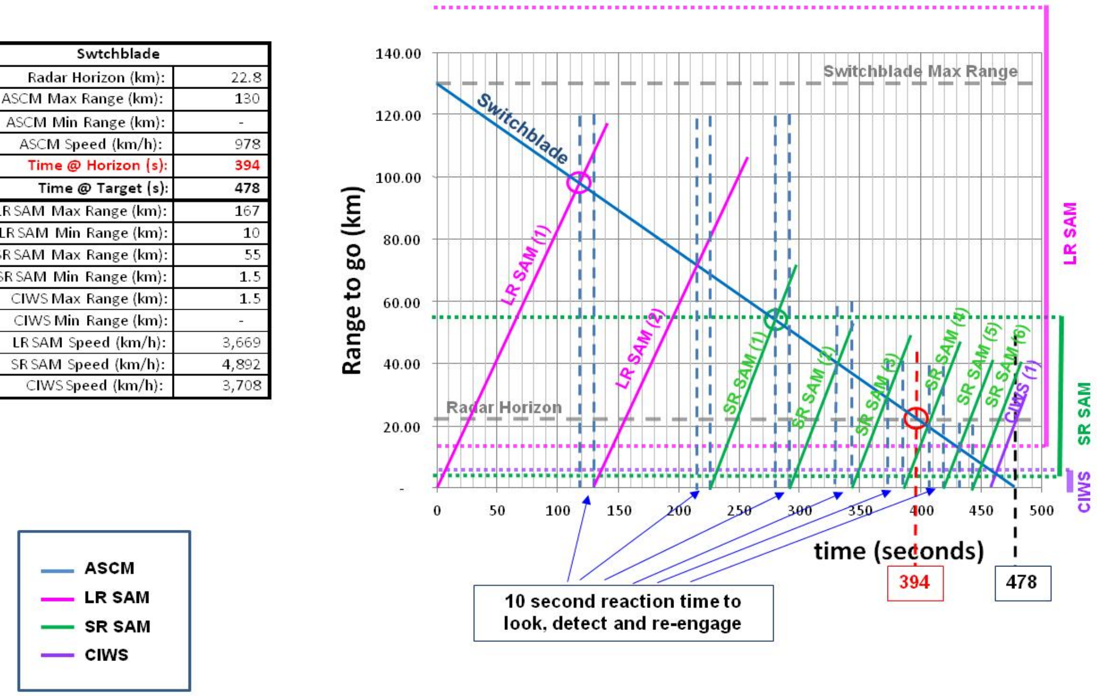


Table 31. ASCM time-line diagrams (7/9).

SWITCHBLADE

Swtchblade	
Radar Horizon (km):	22.8
ASCM Max Range (km):	130
ASCM Min Range (km):	-
ASCM Speed (km/h):	978
Time @ Horizon (s):	394
Time @ Target (s):	478
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708



BRAHMOS

BrahMos	
Radar Horizon (km):	26.2
ASCM Max Range (km):	290
ASCM Min Range (km):	-
ASCM Speed (km/h):	2,446
Time @ Horizon (s):	388
Time @ Target (s):	427
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

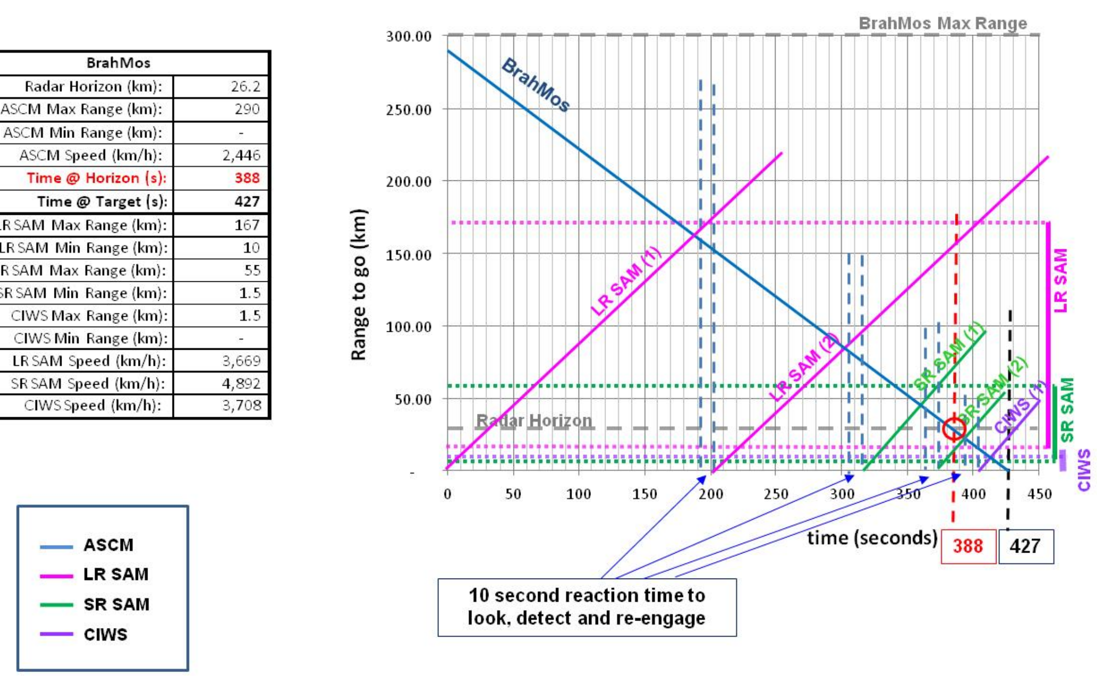


Table 32. ASCM time-line diagrams (8/9).

RBS-15

RBS-15	
Radar Horizon (km):	29.4
ASCM Max Range (km):	200
ASCM Min Range (km):	-
ASCM Speed (km/h):	1101
Time @ Horizon (s):	702
Time @ Target (s):	736
LR SAM Max Range (km):	167
LR SAM Min Range (km):	10
SR SAM Max Range (km):	55
SR SAM Min Range (km):	1.5
CIWS Max Range (km):	1.5
CIWS Min Range (km):	-
LR SAM Speed (km/h):	3,669
SR SAM Speed (km/h):	4,892
CIWS Speed (km/h):	3,708

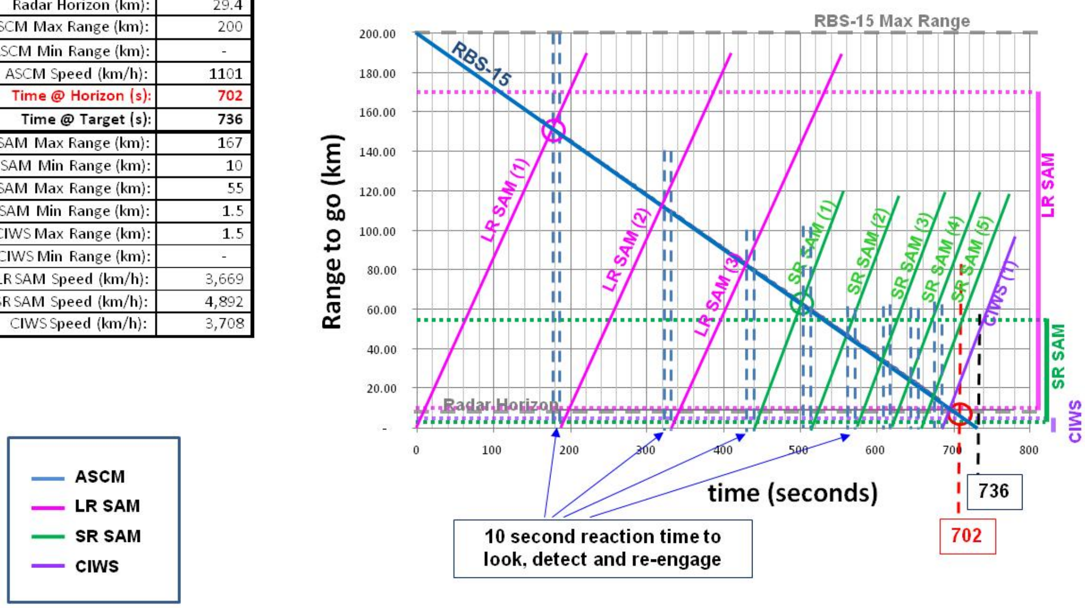
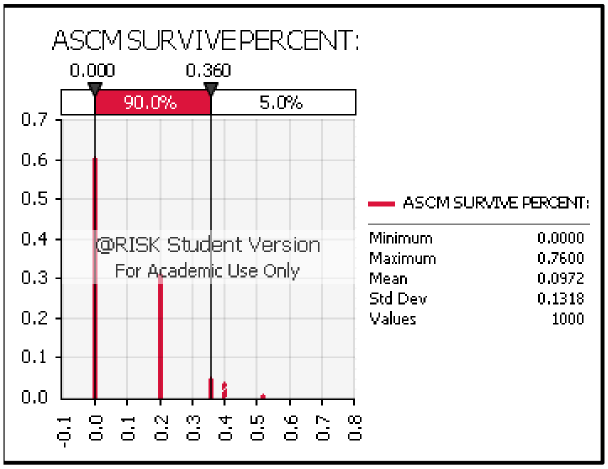
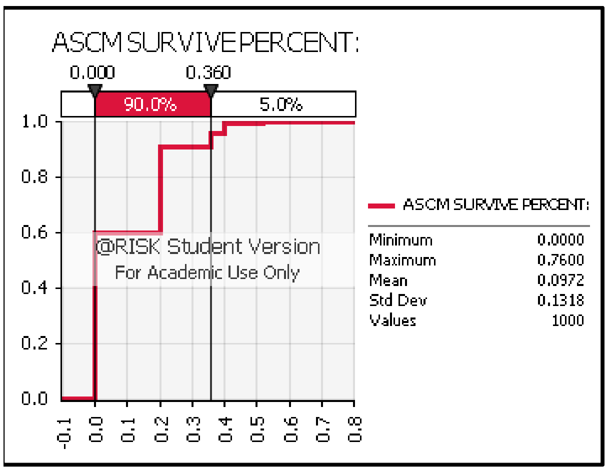


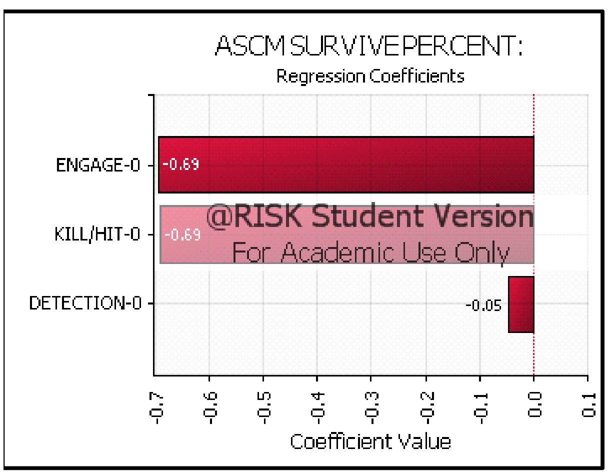
Table 33. ASCM time-line diagrams (9/9).

@RISK Output Report for EXOCET MM-38:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 5:44:07 PM **N=5, Iterations = 1,000**







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	11
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 17:43:58
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	1553424959

Summary Statistics for ASCM SURVIVE PERCENT			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	76.0%	**10%**	0.0%
Mean	9.7%	**15%**	0.0%
Std Dev	13.2%	**20%**	0.0%
Variance	0.017382342	**25%**	0.0%
Skewness	1.15257757	**30%**	0.0%
Kurtosis	3.862116898	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	36.0%	**60%**	0.0%
Right P	95%	**65%**	20.0%
Diff X	36.0%	**70%**	20.0%
Diff P	90%	**75%**	20.0%
#Errors	0	**80%**	20.0%
Filter Min	Off	**85%**	20.0%
Filter Max	Off	**90%**	20.0%
#Filtered	0	**95%**	36.0%

Regression and Rank Information for ASCM SUI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE-0	-0.695	-0.694
2	KILL/HIT-0	-0.692	-0.692
3	DETECTION-0	-0.047	-0.032
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

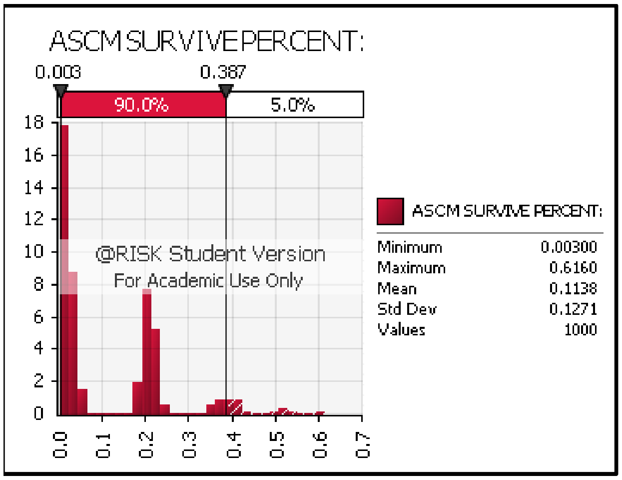
Table 34. @Risk results for EXOCET MM-38.

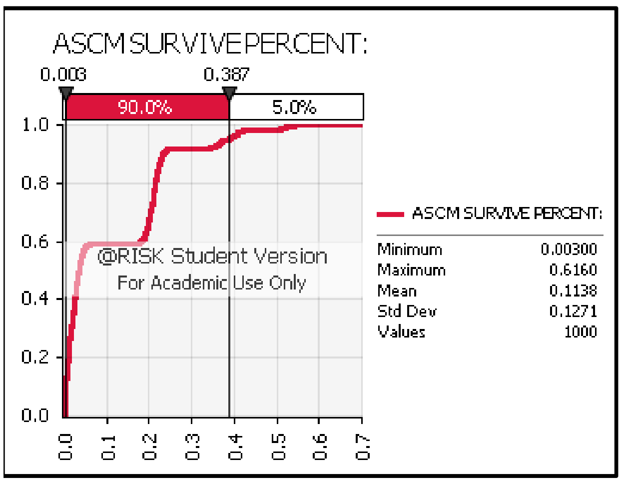
@RISK Output Report for EXOCET MM-38 with Soft Kill:

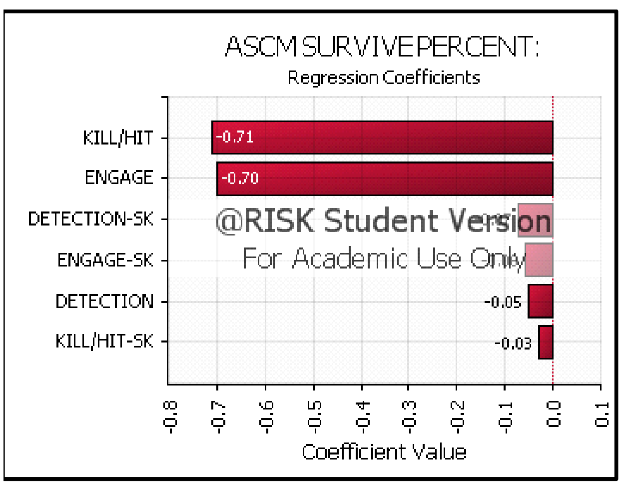
Performed By: Roy Smith

Date: Sunday, March 28, 2010 5:51:17 PM

N=5, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 17:51:07
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	56017614

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	61.6%	10%	0.4%
Mean	11.4%	15%	0.7%
Std Dev	12.7%	20%	1.1%
Variance	0.016144978	25%	1.3%
Skewness	1.121428652	30%	1.8%
Kurtosis	3.671958235	35%	2.2%
Median	3.6%	40%	2.6%
Mode	0.3%	45%	3.0%
Left X	0.3%	50%	3.6%
Left P	5%	55%	4.3%
Right X	38.7%	60%	18.2%
Right P	95%	65%	19.7%
Diff X	38.4%	70%	20.4%
Diff P	90%	75%	21.0%
#Errors	0	80%	21.5%
Filter Min	Off	85%	22.2%
Filter Max	Off	90%	23.3%
#Filtered	0	95%	38.7%

Regression and Rank Information for ASCM SURVI

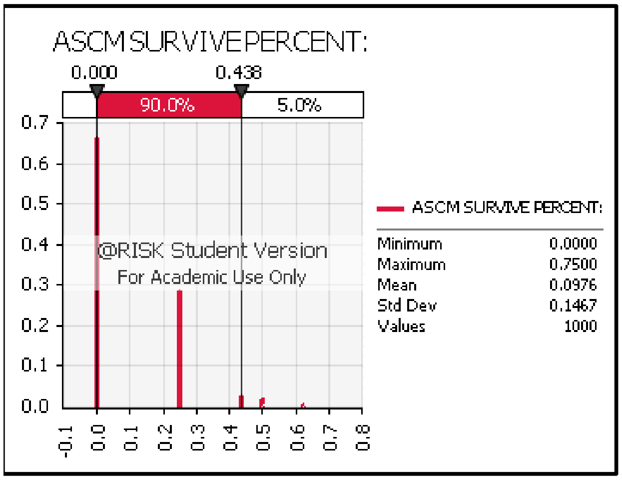
Rank	Name	Regr	Corr
1	KILL/HIT	-0.710	-0.602
2	ENGAGE	-0.700	-0.580
3	DETECTION-SK	-0.071	-0.319
4	ENGAGE-SK	-0.057	-0.206
5	DETECTION	-0.050	-0.070
6	KILL/HIT-SK	-0.028	-0.127
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

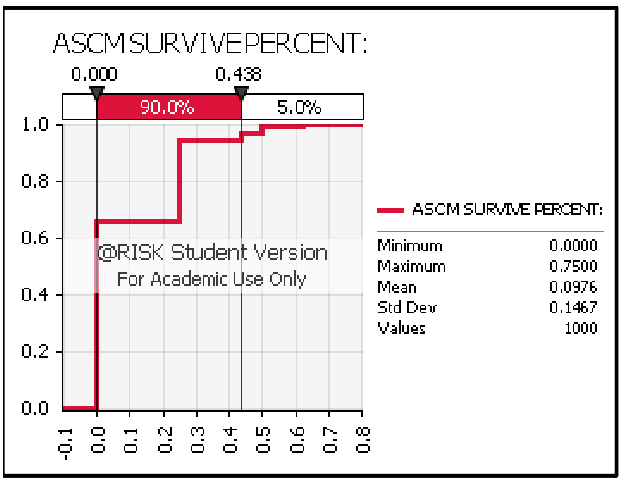
Table 35. @Risk results for EXOCET MM-38 with soft kill.

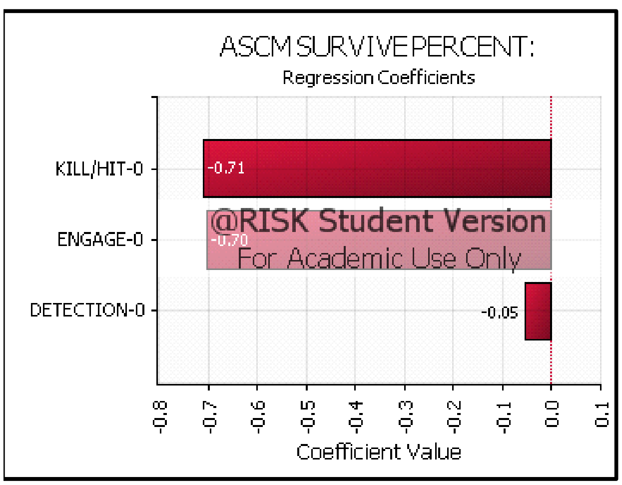
@RISK Output Report for EXOCET SM-39:

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 8:04:31 PM

N=5, Iterations = 1000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:04:22
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	2024513665

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.0%	**5%**	0.0%
Maximum	75.0%	**10%**	0.0%
Mean	9.8%	**15%**	0.0%
Std Dev	14.7%	**20%**	0.0%
Variance	0.021514792	**25%**	0.0%
Skewness	1.263423258	**30%**	0.0%
Kurtosis	3.841028084	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	43.8%	**60%**	0.0%
Right P	95%	**65%**	0.0%
Diff X	43.8%	**70%**	25.0%
Diff P	90%	**75%**	25.0%
#Errors	0	**80%**	25.0%
Filter Min	Off	**85%**	25.0%
Filter Max	Off	**90%**	25.0%
#Filtered	0	**95%**	43.8%

Regression and Rank Information for ASCM SURVI

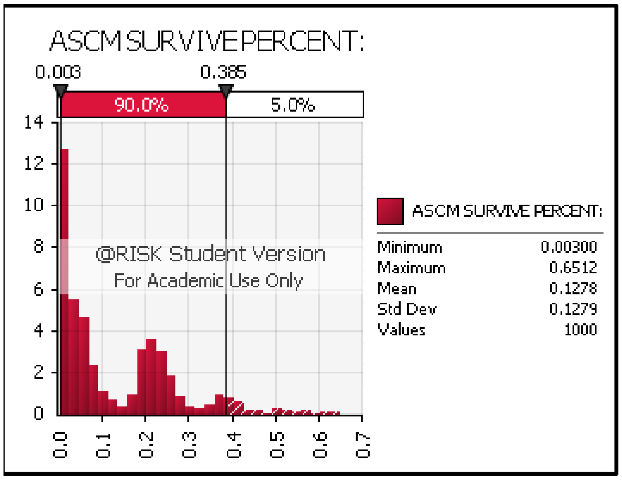
Rank	Name	Regr	Corr
1	KILL/HIT-0	-0.709	-0.684
2	ENGAGE-0	-0.703	-0.688
3	DETECTION-0	-0.053	-0.040
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

Table 36. @Risk results for EXOCET SM-39.

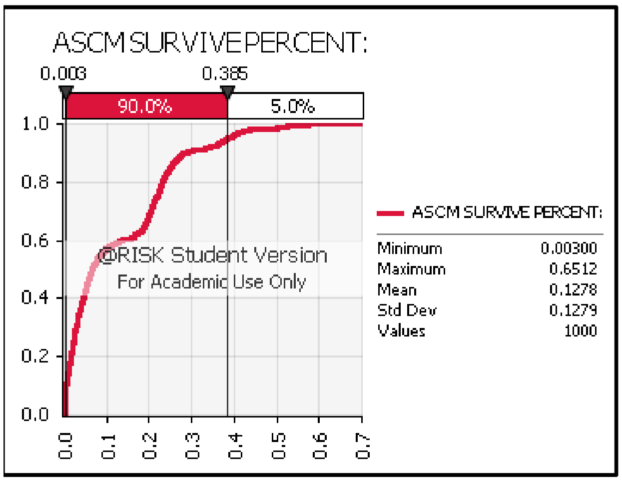
@RISK Output Report for EXOCET SM-39 with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 3:39:21 PM

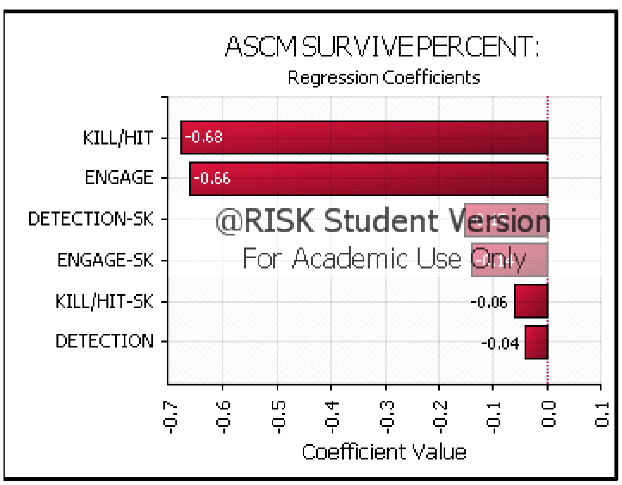
N=5, Iterations = 1,000



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 15:39:12
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1143044635



Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	**5%**	0.3%
Maximum	65.1%	**10%**	0.5%
Mean	12.8%	**15%**	1.1%
Std Dev	12.8%	**20%**	1.7%
Variance	0.016357294	**25%**	2.2%
Skewness	1.077311856	**30%**	3.0%
Kurtosis	3.625860301	**35%**	3.6%
Median	6.6%	**40%**	4.6%
Mode	0.3%	**45%**	5.5%
Left X	0.3%	**50%**	6.6%
Left P	5%	**55%**	8.4%
Right X	38.5%	**60%**	13.5%
Right P	95%	**65%**	18.9%
Diff X	38.2%	**70%**	20.5%
Diff P	90%	**75%**	21.8%
#Errors	0	**80%**	23.2%
Filter Min	Off	**85%**	25.0%
Filter Max	Off	**90%**	28.7%
#Filtered	0	**95%**	38.5%

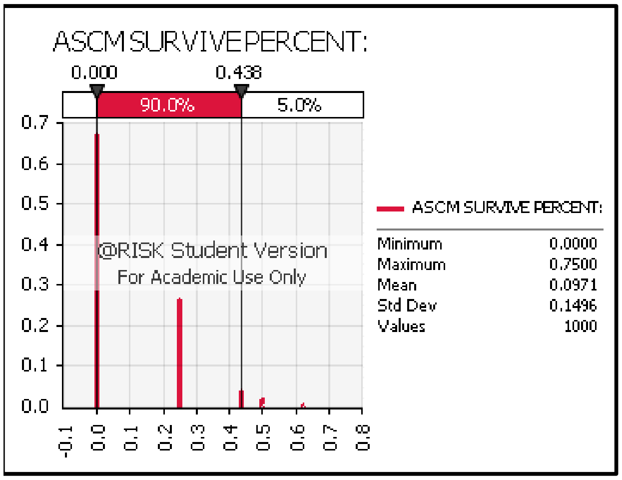


Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.678	-0.617
2	ENGAGE	-0.663	-0.591
3	DETECTION-SK	-0.150	-0.302
4	ENGAGE-SK	-0.139	-0.273
5	KILL/HIT-SK	-0.060	-0.096
6	DETECTION	-0.040	-0.026
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

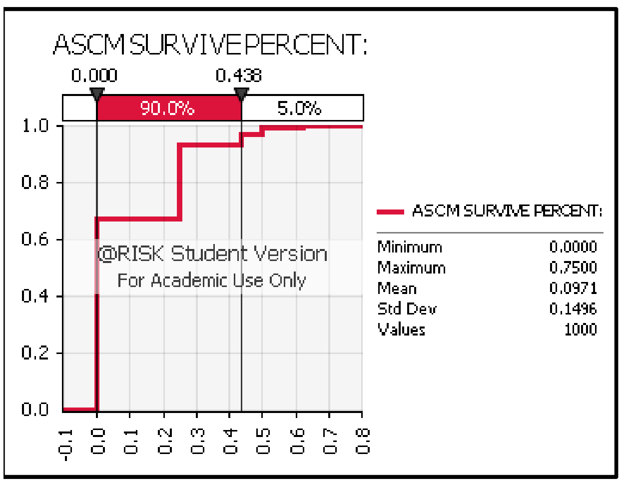
Table 37. @Risk results for EXOCET SM-39 with soft kill.

@RISK Output Report for EXOCET AM-39 / MM-40:

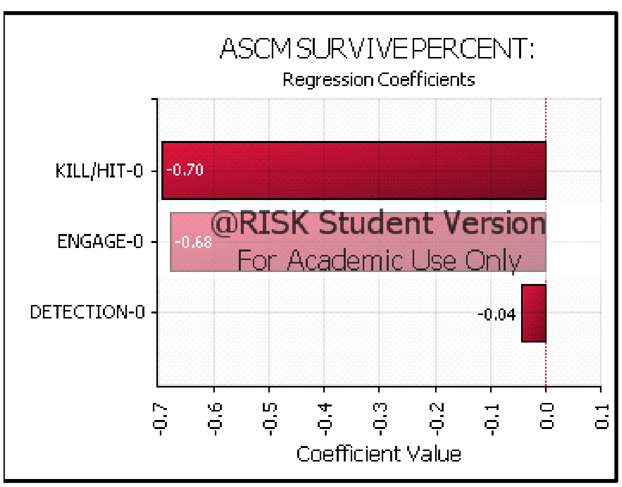
Performed By: Roy Smith
Date: Tuesday, March 30, 2010 10:49:55 PM **N=4, Iterations = 1,000**



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/30/10 22:49:45
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1869708143



Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	75.0%	**10%**	0.0%
Mean	9.7%	**15%**	0.0%
Std Dev	15.0%	**20%**	0.0%
Variance	0.022393816	**25%**	0.0%
Skewness	1.302843875	**30%**	0.0%
Kurtosis	3.833970597	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	43.8%	**60%**	0.0%
Right P	95%	**65%**	0.0%
Diff X	43.8%	**70%**	25.0%
Diff P	90%	**75%**	25.0%
#Errors	0	**80%**	25.0%
Filter Min	Off	**85%**	25.0%
Filter Max	Off	**90%**	25.0%
#Filtered	0	**95%**	43.8%



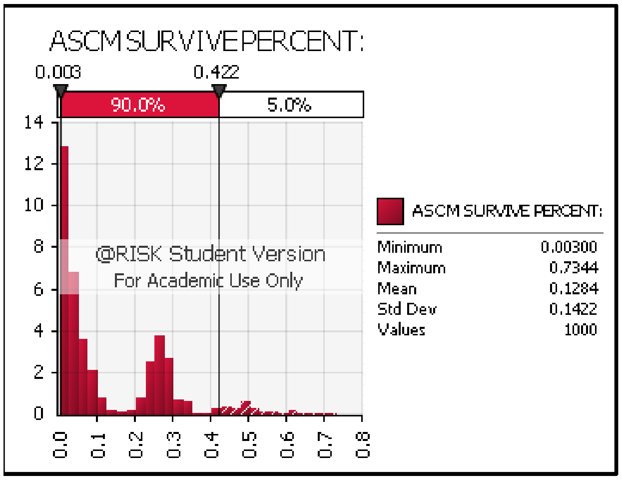
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.695	-0.710
2	ENGAGE-0	-0.679	-0.702
3	DETECTION-0	-0.042	-0.060
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

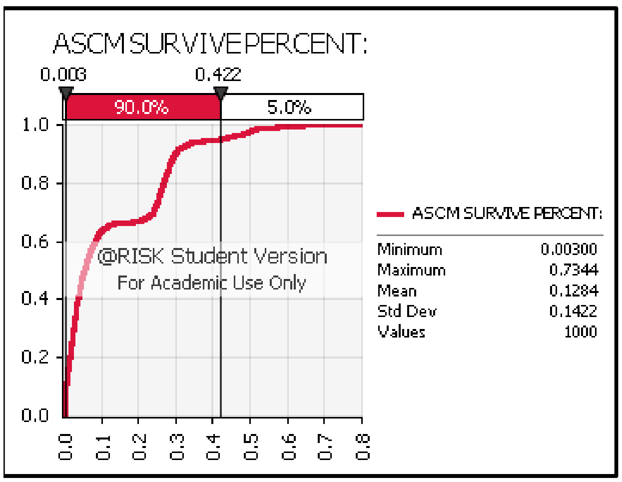
Table 38. @Risk results for EXOCET AM-39/MM-40.

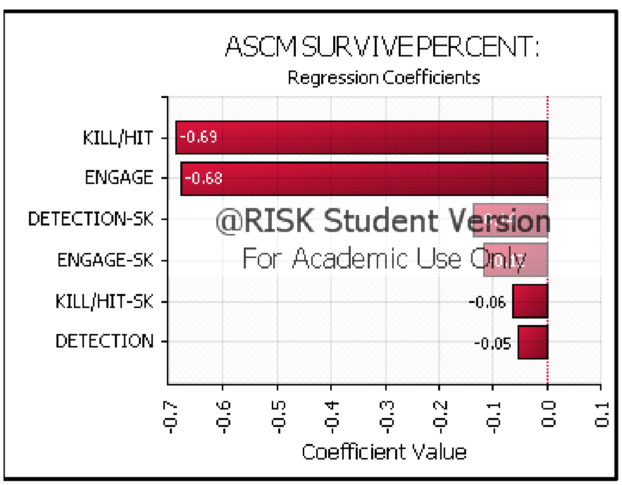
@RISK Output Report for EXOCET AM-39/MM-40 with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 3:47:36 PM

N=4, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 15:47:27
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	286956148

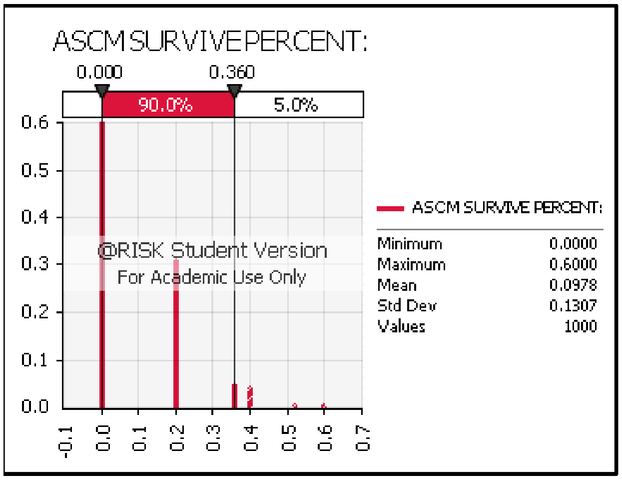
Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	73.4%	10%	0.5%
Mean	12.8%	15%	1.1%
Std Dev	14.2%	20%	1.6%
Variance	0.020216686	25%	2.1%
Skewness	1.227712574	30%	2.6%
Kurtosis	3.900030115	35%	3.2%
Median	5.6%	40%	3.8%
Mode	0.3%	45%	4.5%
Left X	0.3%	50%	5.6%
Left P	5%	55%	6.7%
Right X	42.2%	60%	8.4%
Right P	95%	65%	11.5%
Diff X	41.9%	70%	24.0%
Diff P	90%	75%	25.5%
#Errors	0	80%	26.7%
Filter Min	Off	85%	28.2%
Filter Max	Off	90%	29.7%
#Filtered	0	95%	42.2%

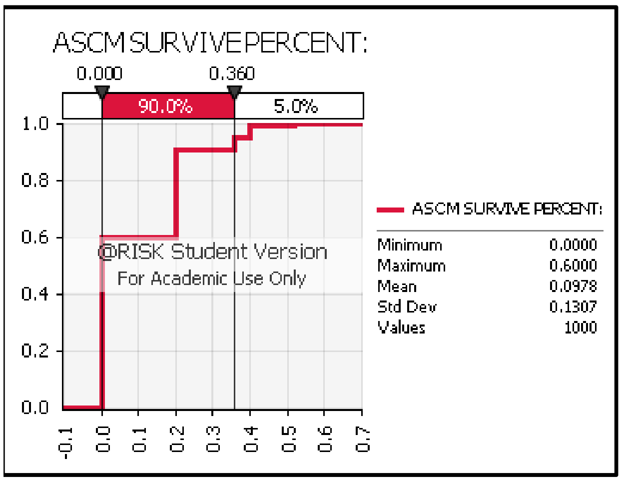
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.688	-0.584
2	ENGAGE	-0.677	-0.558
3	DETECTION-SK	-0.137	-0.322
4	ENGAGE-SK	-0.115	-0.259
5	KILL/HIT-SK	-0.061	-0.148
6	DETECTION	-0.053	-0.045
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

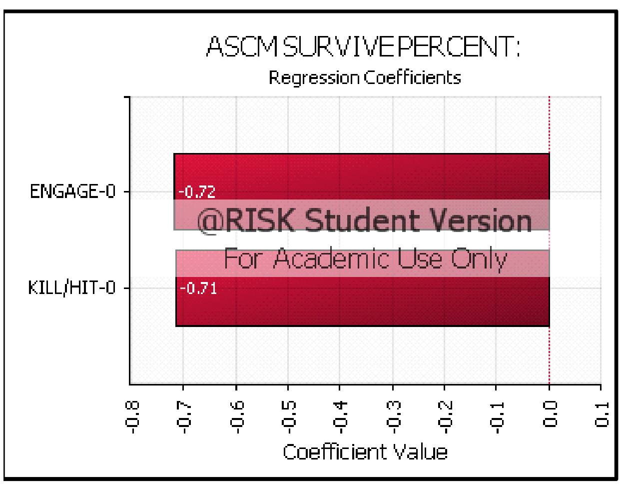
Table 39. @Risk results for EXOCET AM-39/MM-40 with soft kill.

@RISK Output Report for HARPOON RGM-84/UGM-84:

Performed By: Roy Smith
Date: Friday, April 02, 2010 3:25:06 PM **N=5, Iterations = 1,000**







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 15:24:57
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	806135148

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	60.0%	**10%**	0.0%
Mean	9.8%	**15%**	0.0%
Std Dev	13.1%	**20%**	0.0%
Variance	0.017093676	**25%**	0.0%
Skewness	1.035242836	**30%**	0.0%
Kurtosis	3.153596525	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	36.0%	**60%**	20.0%
Right P	95%	**65%**	20.0%
Diff X	36.0%	**70%**	20.0%
Diff P	90%	**75%**	20.0%
#Errors	0	**80%**	20.0%
Filter Min	Off	**85%**	20.0%
Filter Max	Off	**90%**	20.0%
#Filtered	0	**95%**	36.0%

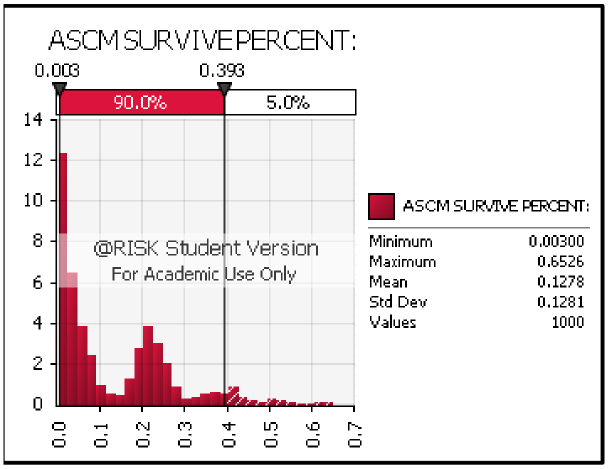
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE-0	-0.716	-0.685
2	KILL/HIT-0	-0.715	-0.683
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

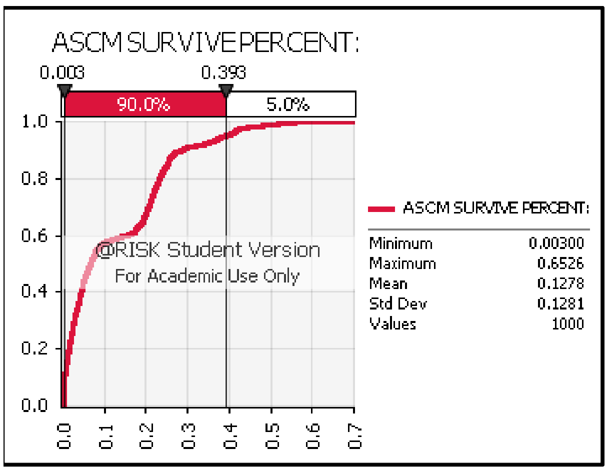
Table 40. @Risk results for HARPOON RGM-84/UGM-84.

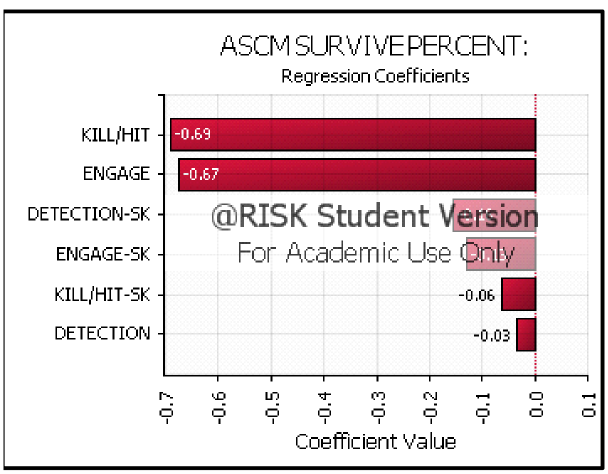
@RISK Output Report for HARPOON RGM-84/UGM-84 with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 3:32:09 PM

N=5, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 15:32:00
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	817750817

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	**5%**	0.3%
Maximum	65.3%	**10%**	0.5%
Mean	12.8%	**15%**	1.0%
Std Dev	12.8%	**20%**	1.6%
Variance	0.016419957	**25%**	2.1%
Skewness	1.043407544	**30%**	2.8%
Kurtosis	3.492029779	**35%**	3.7%
Median	6.7%	**40%**	4.5%
Mode	0.3%	**45%**	5.3%
Left X	0.3%	**50%**	6.7%
Left P	5%	**55%**	8.2%
Right X	39.3%	**60%**	15.4%
Right P	95%	**65%**	19.3%
Diff X	39.0%	**70%**	20.8%
Diff P	90%	**75%**	21.9%
#Errors	0	**80%**	23.4%
Filter Min	Off	**85%**	25.1%
Filter Max	Off	**90%**	28.4%
#Filtered	0	**95%**	39.3%

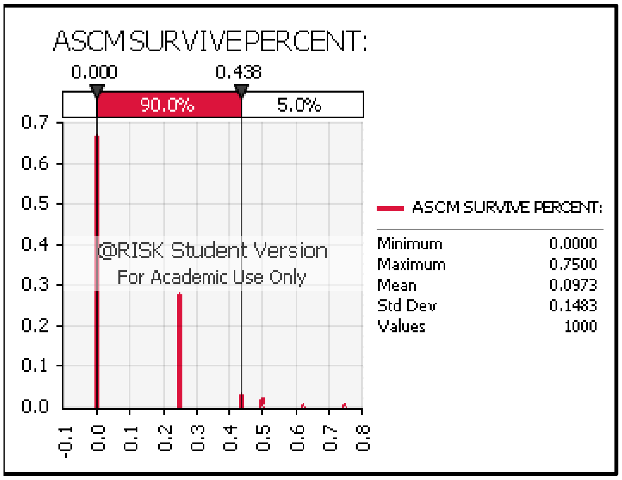
Regression and Rank Information for ASCM SURVIVE

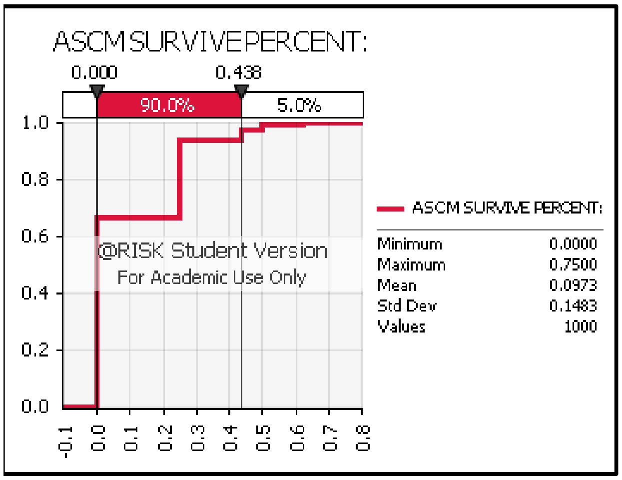
Rank	Name	Regr	Corr
1	KILL/HIT	-0.692	-0.601
2	ENGAGE	-0.675	-0.592
3	DETECTION-SK	-0.156	-0.285
4	ENGAGE-SK	-0.131	-0.264
5	KILL/HIT-SK	-0.061	-0.139
6	DETECTION	-0.033	-0.046
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

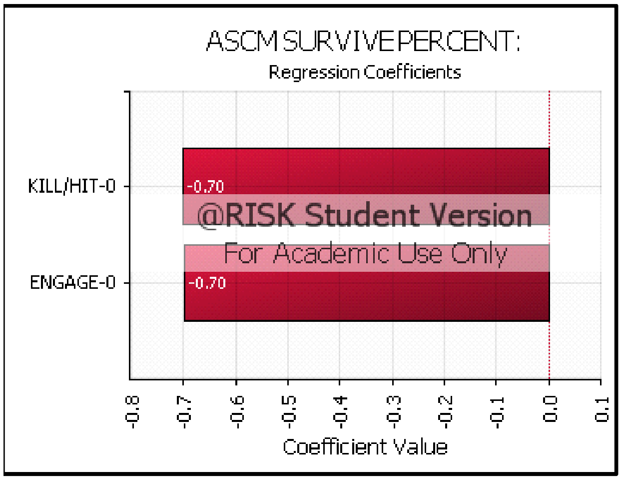
Table 41. @Risk results for HARPOON RGM-84/UGM-84 with soft kill.

@RISK Output Report for HARPOON AGM-84:

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 8:23:24 PM **N=4, Iterations = 1,000**







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:23:15
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1817601450

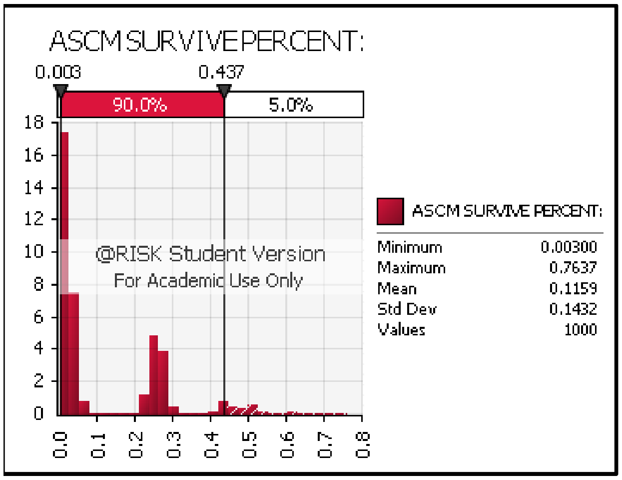
Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	75.0%	10%	0.0%
Mean	9.7%	15%	0.0%
Std Dev	14.8%	20%	0.0%
Variance	0.021985857	25%	0.0%
Skewness	1.328233469	30%	0.0%
Kurtosis	4.168840493	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	43.8%	60%	0.0%
Right P	95%	65%	0.0%
Diff X	43.8%	70%	25.0%
Diff P	90%	75%	25.0%
#Errors	0	80%	25.0%
Filter Min	Off	85%	25.0%
Filter Max	Off	90%	25.0%
#Filtered	0	95%	43.8%

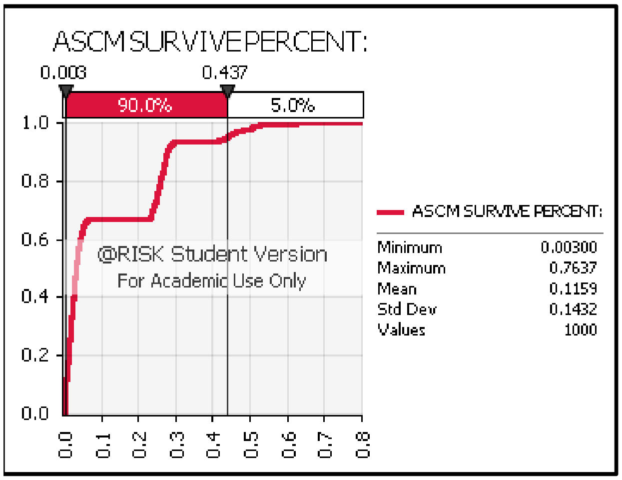
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.701	-0.695
2	ENGAGE-0	-0.697	-0.691
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

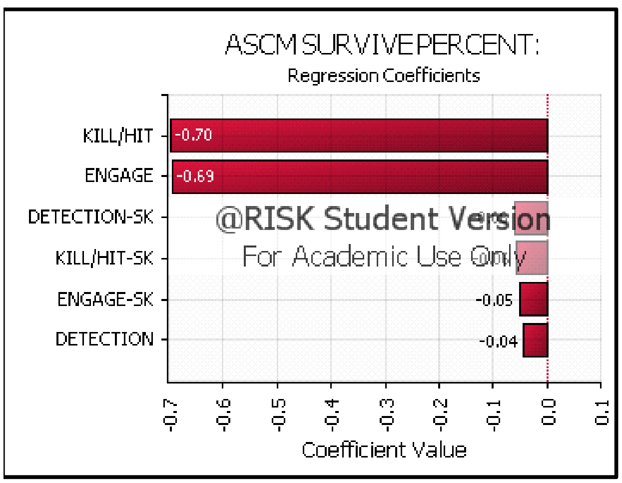
Table 42. @Risk results for HARPOON AGM-84.

@RISK Output Report for HARPOON AGM-84 with Soft Kill:

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 8:30:41 PM **N=5, Iterations = 1,000**





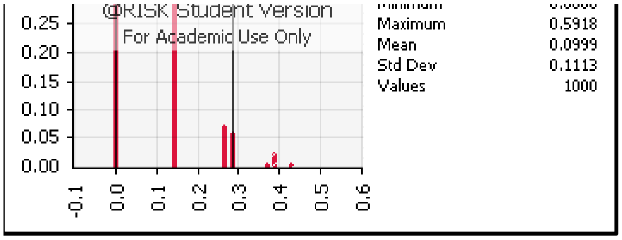


Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:30:30
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1879483443

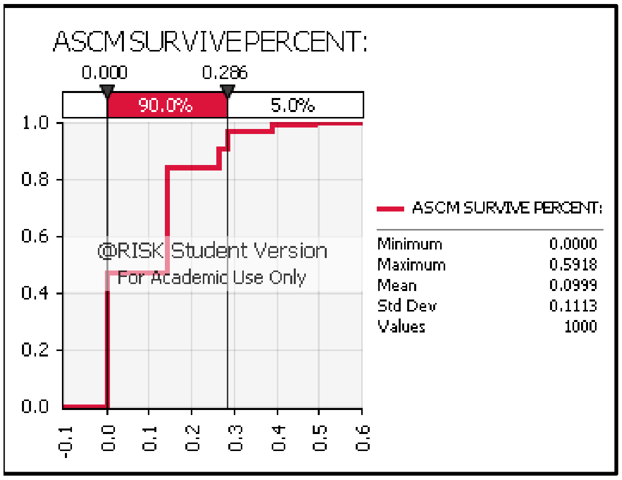
Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	76.4%	10%	0.5%
Mean	11.6%	15%	1.0%
Std Dev	14.3%	20%	1.3%
Variance	0.020506462	25%	1.6%
Skewness	1.272970895	30%	1.9%
Kurtosis	3.813396575	35%	2.2%
Median	3.2%	40%	2.6%
Mode	0.3%	45%	2.9%
Left X	0.3%	50%	3.2%
Left P	5%	55%	3.7%
Right X	43.7%	60%	4.4%
Right P	95%	65%	5.6%
Diff X	43.4%	70%	23.9%
Diff P	90%	75%	25.0%
#Errors	0	80%	25.9%
Filter Min	Off	85%	27.0%
Filter Max	Off	90%	27.8%
#Filtered	0	95%	43.7%

Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.696	-0.592
2	ENGAGE	-0.694	-0.560
3	DETECTION-SK	-0.061	-0.303
4	KILL/HIT-SK	-0.056	-0.243
5	ENGAGE-SK	-0.050	-0.125
6	DETECTION	-0.045	-0.051
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

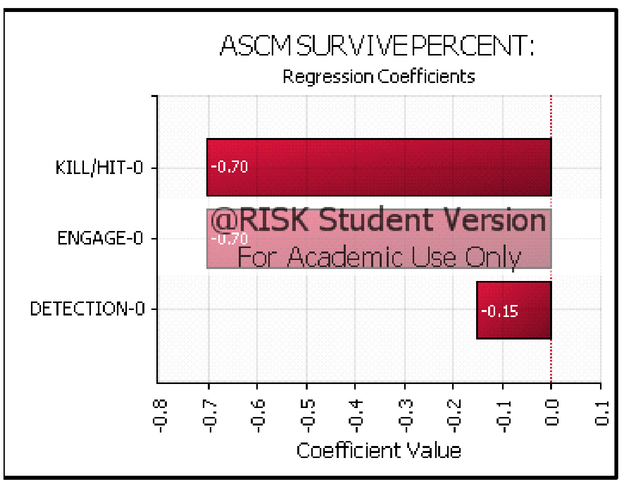
Table 43. @Risk results for HARPOON AGM-84 with soft kill.



Simulation Duration	00:00:09
Random # Generator	Mersenne Twister
Random Seed	308565902

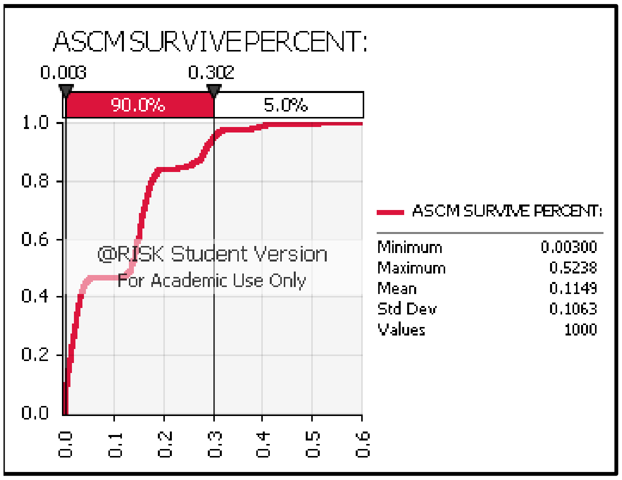


Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	59.2%	**10%**	0.0%
Mean	10.0%	**15%**	0.0%
Std Dev	11.1%	**20%**	0.0%
Variance	0.012390863	**25%**	0.0%
Skewness	0.92157812	**30%**	0.0%
Kurtosis	3.460939545	**35%**	0.0%
Median	14.3%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	14.3%
Left P	5%	**55%**	14.3%
Right X	28.6%	**60%**	14.3%
Right P	95%	**65%**	14.3%
Diff X	28.6%	**70%**	14.3%
Diff P	90%	**75%**	14.3%
#Errors	0	**80%**	14.3%
Filter Min	Off	**85%**	26.5%
Filter Max	Off	**90%**	26.5%
#Filtered	0	**95%**	28.6%

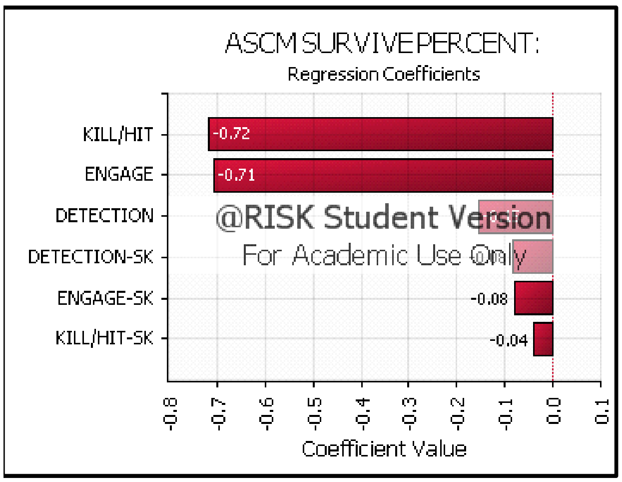


Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.704	-0.667
2	ENGAGE-0	-0.702	-0.668
3	DETECTION-0	-0.153	-0.161
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

Table 44. @Risk results for SILKWORM.



Minimum	0.3%	**5%**	0.3%
Maximum	52.4%	**10%**	0.5%
Mean	11.5%	**15%**	0.9%
Std Dev	10.6%	**20%**	1.3%
Variance	0.011305795	**25%**	1.8%
Skewness	0.800668741	**30%**	2.2%
Kurtosis	3.057469861	**35%**	2.7%
Median	13.5%	**40%**	3.3%
Mode	0.3%	**45%**	4.3%
Left X	0.3%	**50%**	13.5%
Left P	5%	**55%**	14.4%
Right X	30.2%	**60%**	15.0%
Right P	95%	**65%**	15.5%
Diff X	29.9%	**70%**	16.1%
Diff P	90%	**75%**	16.8%
#Errors	0	**80%**	17.7%
Filter Min	Off	**85%**	24.7%
Filter Max	Off	**90%**	28.3%
#Filtered	0	**95%**	30.2%



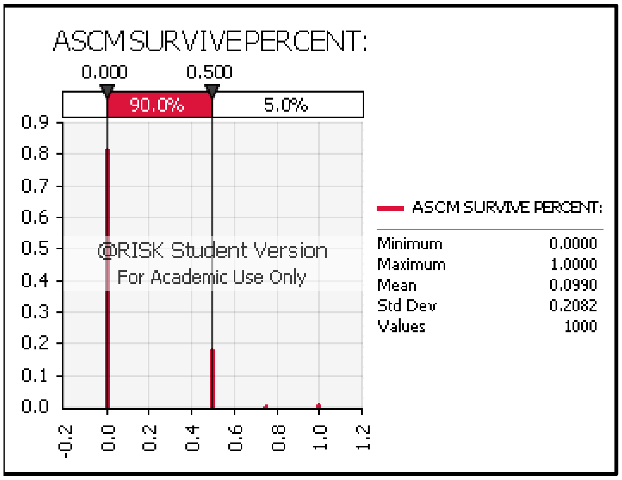
Regression and Rank Information for ASCM SURVI

Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.718	-0.611
2	ENGAGE	-0.708	-0.599
3	DETECTION	-0.154	-0.109
4	DETECTION-SK	-0.084	-0.311
5	ENGAGE-SK	-0.078	-0.165
6	KILL/HIT-SK	-0.039	-0.146
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

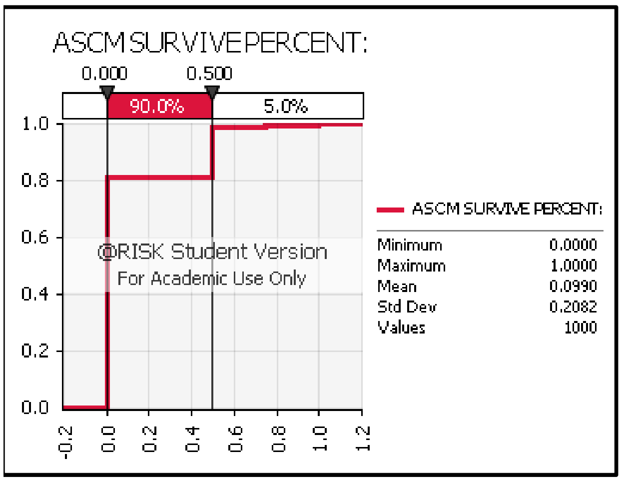
Table 45. @Risk results for SILKWORM with soft kill.

@RISK Output Report for SIZZLER (91RE2):

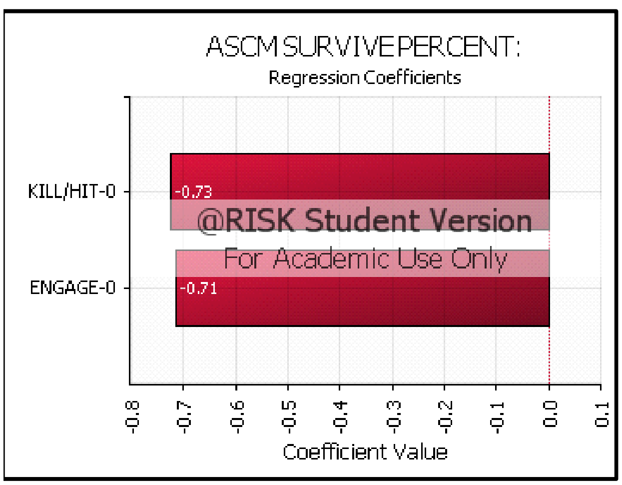
Performed By: Roy Smith
Date: Friday, April 02, 2010 10:44:26 AM **N=2, Iterations = 1,000**



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 10:44:17
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	1368055549



Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	100.0%	10%	0.0%
Mean	9.9%	15%	0.0%
Std Dev	20.8%	20%	0.0%
Variance	0.043367367	25%	0.0%
Skewness	1.784599415	30%	0.0%
Kurtosis	4.852270913	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	50.0%	60%	0.0%
Right P	95%	65%	0.0%
Diff X	50.0%	70%	0.0%
Diff P	90%	75%	0.0%
#Errors	0	80%	0.0%
Filter Min	Off	85%	50.0%
Filter Max	Off	90%	50.0%
#Filtered	0	95%	50.0%

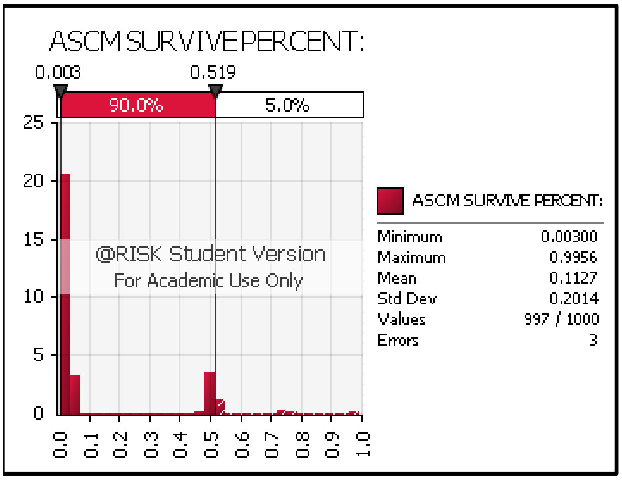


Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.726	-0.685
2	ENGAGE-0	-0.714	-0.684
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

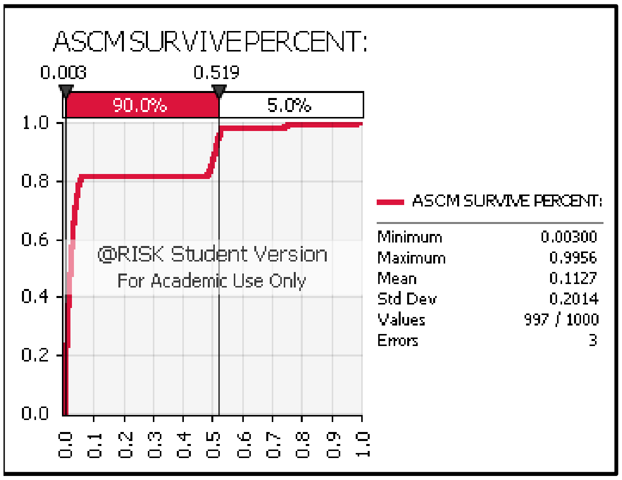
Table 46. @Risk results for SIZZLER 91RE2.

@RISK Output Report for SIZZLER (91RE2) with Soft Kill:

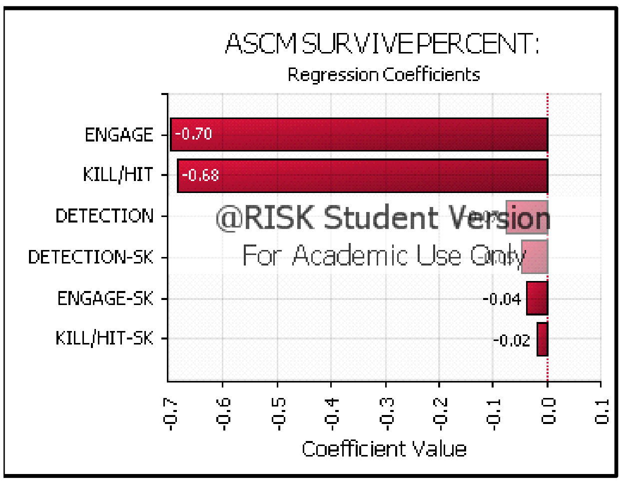
Performed By: Roy Smith
Date: Friday, April 02, 2010 10:38:48 AM **N=2, Iterations = 1,000**



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 10:38:39
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	685713423



Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	99.6%	10%	0.3%
Mean	11.3%	15%	0.5%
Std Dev	20.1%	20%	0.7%
Variance	0.040572562	25%	0.9%
Skewness	1.807667971	30%	1.1%
Kurtosis	4.830256952	35%	1.4%
Median	2.2%	40%	1.6%
Mode	0.3%	45%	1.9%
Left X	0.3%	50%	2.2%
Left P	5%	55%	2.4%
Right X	51.9%	60%	2.7%
Right P	95%	65%	3.1%
Diff X	51.6%	70%	3.7%
Diff P	90%	75%	4.3%
#Errors	3	80%	5.3%
Filter Min	Off	85%	49.4%
Filter Max	Off	90%	50.7%
#Filtered	0	95%	51.9%

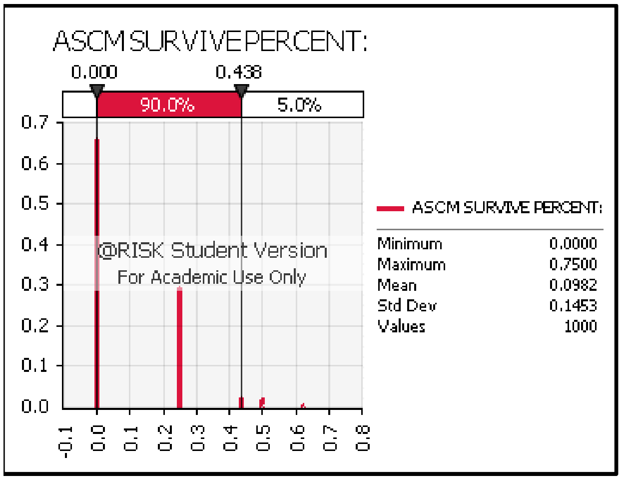


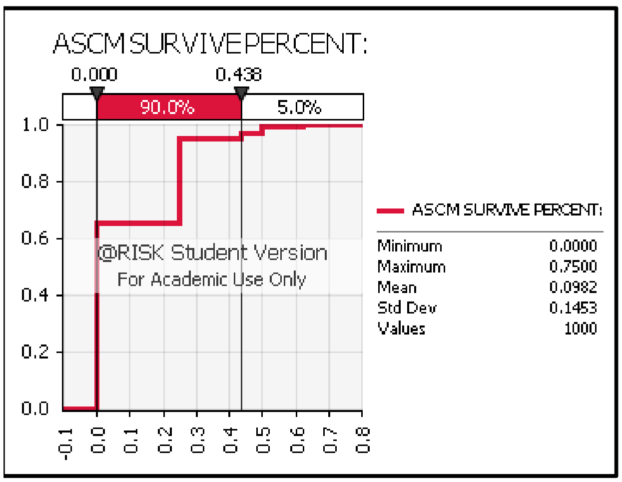
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE	-0.697	-0.469
2	KILL/HIT	-0.685	-0.471
3	DETECTION	-0.075	-0.035
4	DETECTION-SK	-0.046	-0.479
5	ENGAGE-SK	-0.036	-0.348
6	KILL/HIT-SK	-0.019	-0.155
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

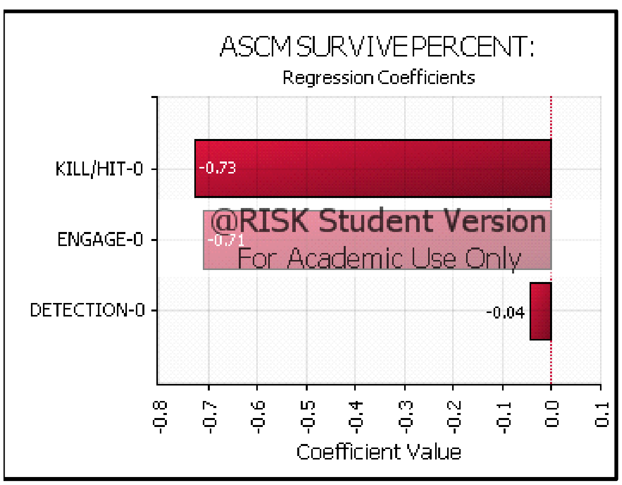
Table 47. @Risk results for SIZZLER 91RE2 with soft kill.

@RISK Output Report for SIZZLER (3M-14E):

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 8:52:21 PM **N=4, Iterations = 1,000**







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:52:12
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1975281624

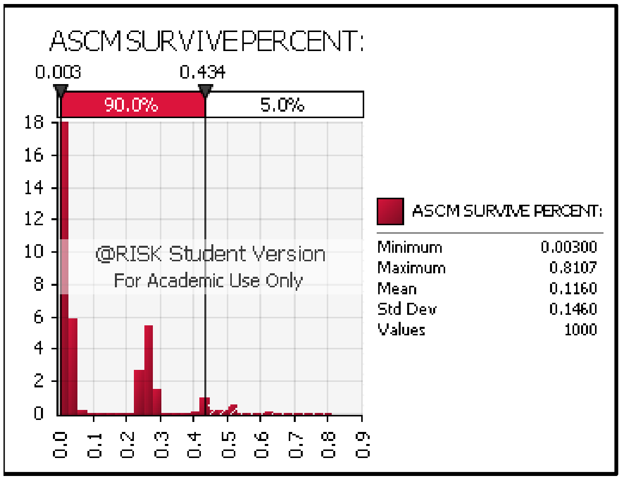
Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	75.0%	**10%**	0.0%
Mean	9.8%	**15%**	0.0%
Std Dev	14.5%	**20%**	0.0%
Variance	0.021110794	**25%**	0.0%
Skewness	1.22228952	**30%**	0.0%
Kurtosis	3.74324383	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	43.8%	**60%**	0.0%
Right P	95%	**65%**	0.0%
Diff X	43.8%	**70%**	25.0%
Diff P	90%	**75%**	25.0%
#Errors	0	**80%**	25.0%
Filter Min	Off	**85%**	25.0%
Filter Max	Off	**90%**	25.0%
#Filtered	0	**95%**	43.8%

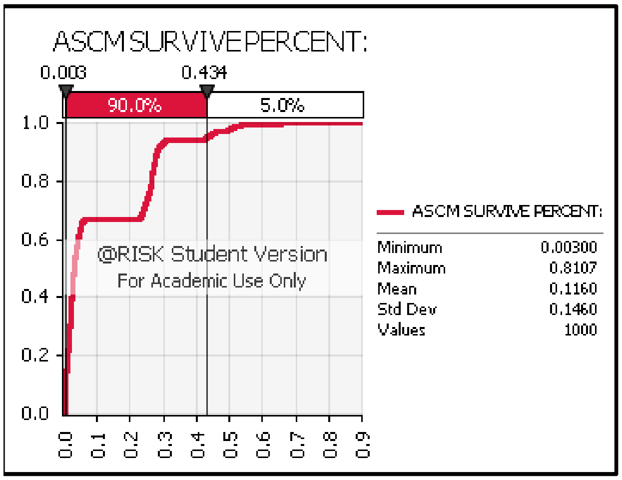
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.727	-0.678
2	ENGAGE-0	-0.710	-0.672
3	DETECTION-0	-0.043	-0.061
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

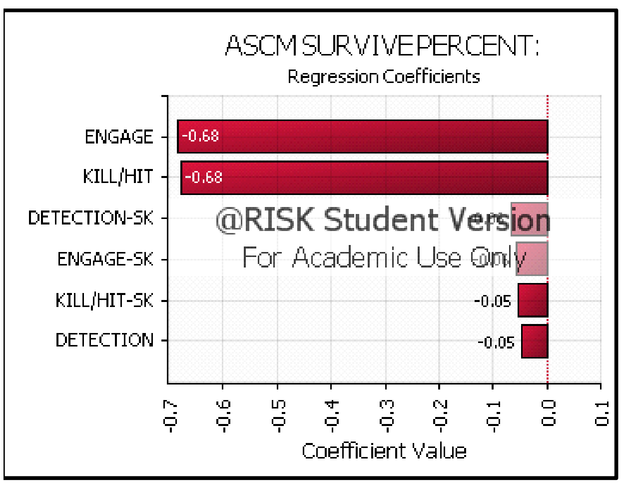
Table 48. @Risk results for SIZZLER 3M14E.

@RISK Output Report for SIZZLER (3M-14E) with Soft Kill:

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 8:42:56 PM
N=4, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:42:47
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1444668006

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	81.1%	10%	0.4%
Mean	11.6%	15%	0.8%
Std Dev	14.6%	20%	1.2%
Variance	0.021311053	25%	1.5%
Skewness	1.329775648	30%	1.8%
Kurtosis	4.193282357	35%	2.1%
Median	3.1%	40%	2.4%
Mode	0.3%	45%	2.6%
Left X	0.3%	50%	3.1%
Left P	5%	55%	3.5%
Right X	43.4%	60%	4.2%
Right P	95%	65%	5.3%
Diff X	43.1%	70%	24.1%
Diff P	90%	75%	25.5%
#Errors	0	80%	26.5%
Filter Min	Off	85%	27.2%
Filter Max	Off	90%	28.2%
#Filtered	0	95%	43.4%

Regression and Rank Information for ASCM SURVI

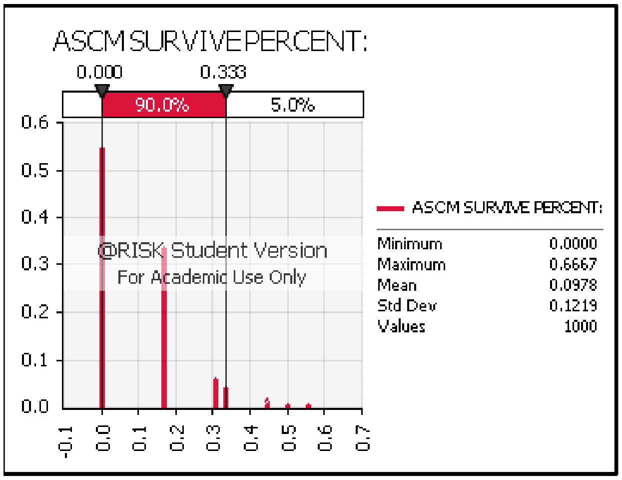
Rank	Name	Regr	Corr
1	ENGAGE	-0.684	-0.582
2	KILL/HIT	-0.679	-0.577
3	DETECTION-SK	-0.065	-0.291
4	ENGAGE-SK	-0.056	-0.257
5	KILL/HIT-SK	-0.052	-0.265
6	DETECTION	-0.047	-0.019
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

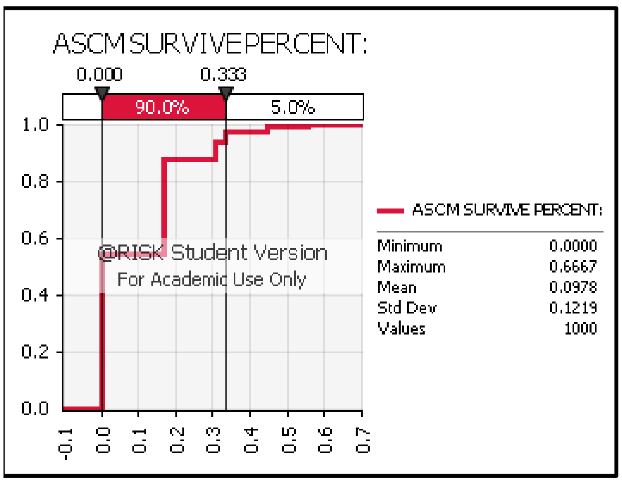
Table 49. @Risk results for SIZZLER 91 3M14E with soft kill.

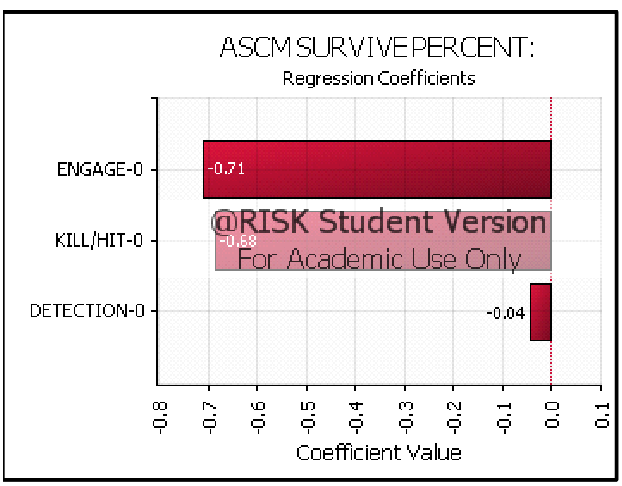
@RISK Output Report for SACCADE C-802:

Performed By: Roy Smith
Date: Friday, April 02, 2010 10:47:41 AM

N=6, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 10:47:32
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	1523317619

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	66.7%	10%	0.0%
Mean	9.8%	15%	0.0%
Std Dev	12.2%	20%	0.0%
Variance	0.01486641	25%	0.0%
Skewness	1.09151962	30%	0.0%
Kurtosis	3.795525641	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	16.7%
Right X	33.3%	60%	16.7%
Right P	95%	65%	16.7%
Diff X	33.3%	70%	16.7%
Diff P	90%	75%	16.7%
#Errors	0	80%	16.7%
Filter Min	Off	85%	16.7%
Filter Max	Off	90%	30.6%
#Filtered	0	95%	33.3%

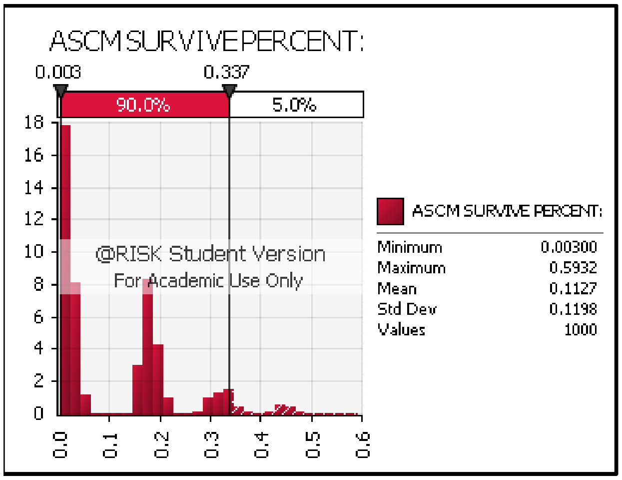
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE-0	-0.708	-0.703
2	KILL/HIT-0	-0.685	-0.683
3	DETECTION-0	-0.043	-0.026
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

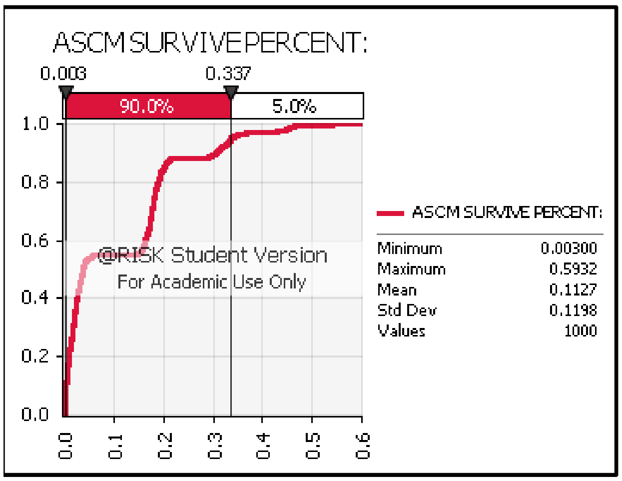
Table 50. @Risk results for SACCADE C-802.

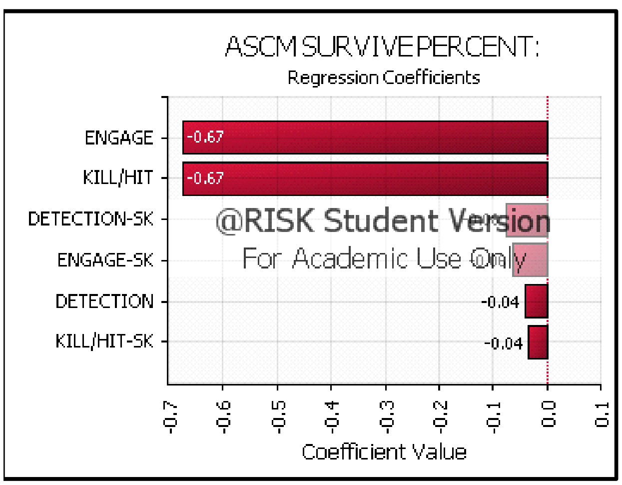
@RISK Output Report for SACCADE C-802 with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 10:52:46 AM

N=6, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 10:52:37
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	2072293763

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	59.3%	10%	0.4%
Mean	11.3%	15%	0.7%
Std Dev	12.0%	20%	1.1%
Variance	0.01435744	25%	1.5%
Skewness	1.092317766	30%	1.8%
Kurtosis	3.681302579	35%	2.2%
Median	3.9%	40%	2.6%
Mode	0.3%	45%	3.2%
Left X	0.3%	50%	3.9%
Left P	5%	55%	14.7%
Right X	33.7%	60%	16.4%
Right P	95%	65%	17.3%
Diff X	33.4%	70%	17.7%
Diff P	90%	75%	18.2%
#Errors	0	80%	19.1%
Filter Min	Off	85%	20.2%
Filter Max	Off	90%	30.5%
#Filtered	0	95%	33.7%

Regression and Rank Information for ASCM SURVI

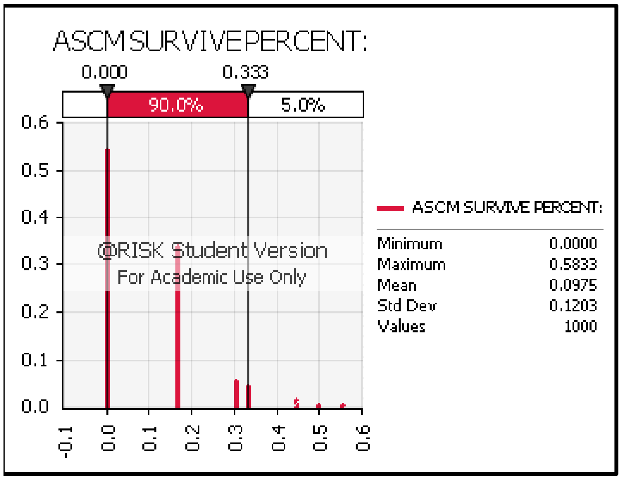
Rank	Name	Regr	Corr
1	ENGAGE	-0.675	-0.635
2	KILL/HIT	-0.674	-0.625
3	DETECTION-SK	-0.075	-0.316
4	ENGAGE-SK	-0.064	-0.247
5	DETECTION	-0.040	-0.023
6	KILL/HIT-SK	-0.035	-0.117
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

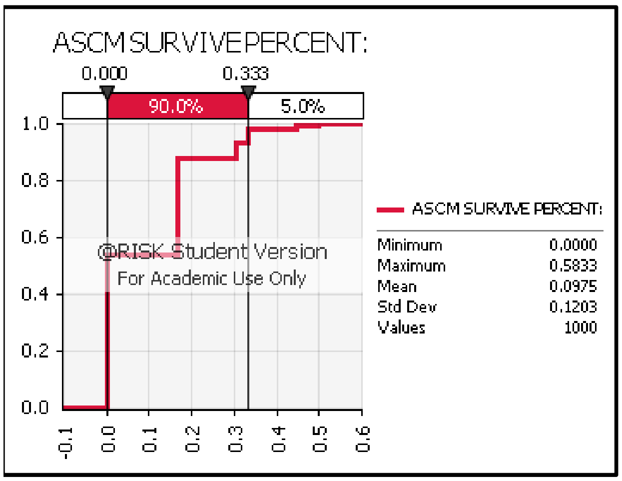
Table 51. @Risk results for SACCADE C-802 with soft kill.

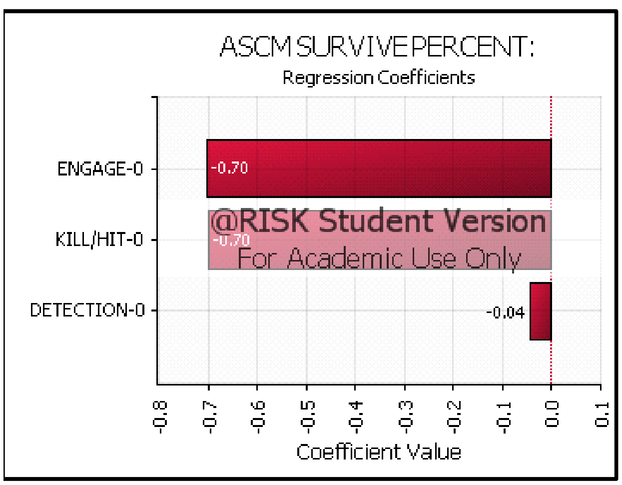
@RISK Output Report for SACCADE CAS-8:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 4:51:27 PM

N = 6, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 16:51:17
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1833996084

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	**5%**	0.0%
Maximum	58.3%	**10%**	0.0%
Mean	9.8%	**15%**	0.0%
Std Dev	12.0%	**20%**	0.0%
Variance	0.014481981	**25%**	0.0%
Skewness	1.022657006	**30%**	0.0%
Kurtosis	3.4620333	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	16.7%
Right X	33.3%	**60%**	16.7%
Right P	95%	**65%**	16.7%
Diff X	33.3%	**70%**	16.7%
Diff P	90%	**75%**	16.7%
#Errors	0	**80%**	16.7%
Filter Min	Off	**85%**	16.7%
Filter Max	Off	**90%**	30.6%
#Filtered	0	**95%**	33.3%

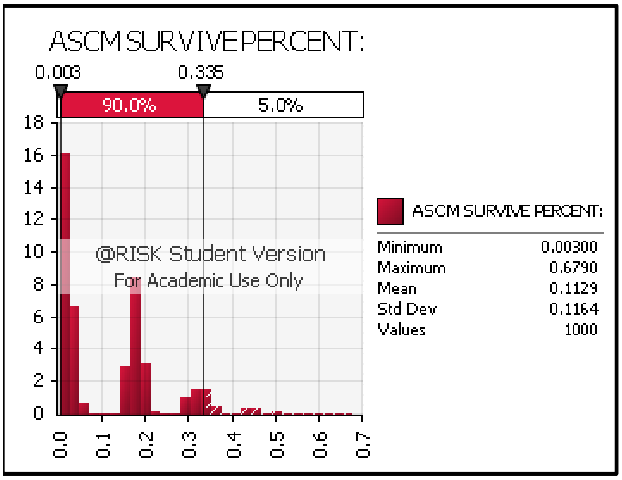
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE-0	-0.702	-0.693
2	KILL/HIT-0	-0.697	-0.686
3	DETECTION-0	-0.043	-0.026
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

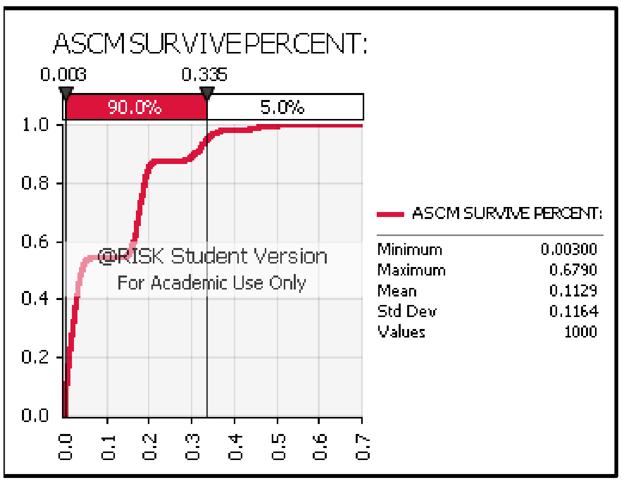
Table 52. @Risk results for SACCADE CAS-8.

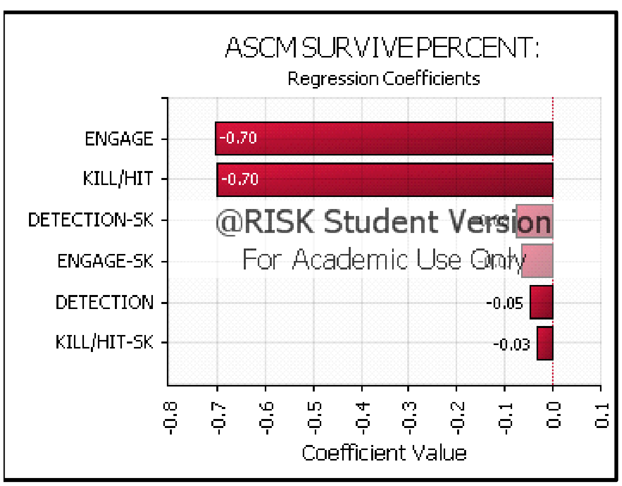
@RISK Output Report for SACCADE CAS-8 wit Soft Kill:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 9:48:35 PM

N = 6, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 21:48:26
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	358303788

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	67.9%	10%	0.5%
Mean	11.3%	15%	0.9%
Std Dev	11.6%	20%	1.2%
Variance	0.013547537	25%	1.6%
Skewness	1.03856592	30%	2.0%
Kurtosis	3.651424441	35%	2.5%
Median	4.2%	40%	2.8%
Mode	0.3%	45%	3.4%
Left X	0.3%	50%	4.2%
Left P	5%	55%	14.8%
Right X	33.5%	60%	16.4%
Right P	95%	65%	17.1%
Diff X	33.2%	70%	17.7%
Diff P	90%	75%	18.3%
#Errors	0	80%	18.9%
Filter Min	Off	85%	19.8%
Filter Max	Off	90%	30.5%
#Filtered	0	95%	33.5%

Regression and Rank Information for ASCM SURVI

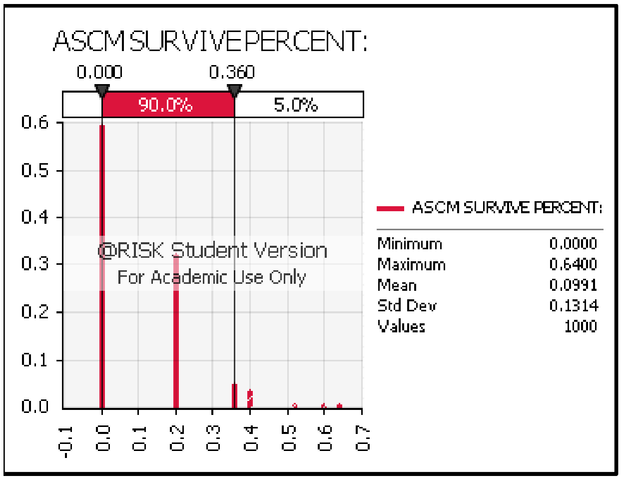
Rank	Name	Regr	Corr
1	ENGAGE	-0.703	-0.610
2	KILL/HIT	-0.700	-0.627
3	DETECTION-SK	-0.075	-0.248
4	ENGAGE-SK	-0.067	-0.151
5	DETECTION	-0.047	-0.039
6	KILL/HIT-SK	-0.034	-0.151
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

Table 53. @Risk results for SACCADE CAS-8 with soft kill.

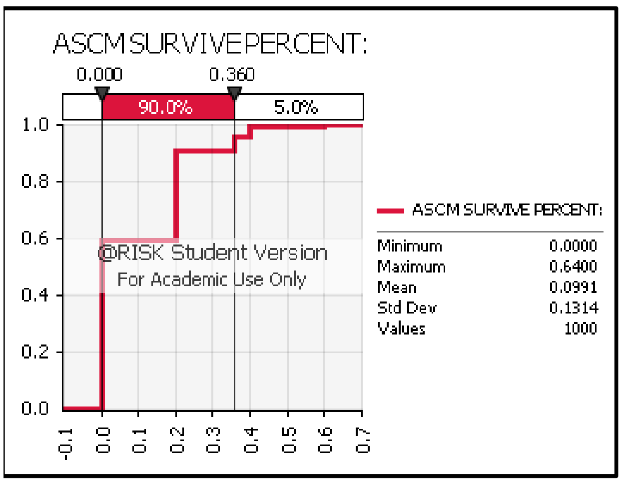
@RISK Output Report for SARDINE:

Performed By: Roy Smith
Date: Friday, April 02, 2010 1:27:55 PM

N = 5, Iterations = 1,000

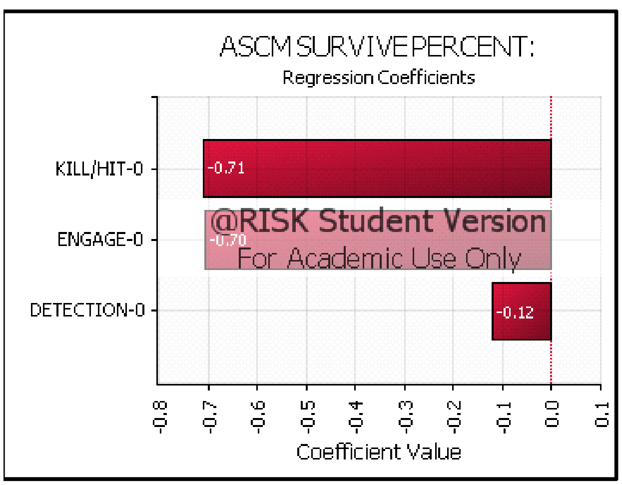


Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 13:27:47
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	1703790342



Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.0%	5%	0.0%
Maximum	64.0%	10%	0.0%
Mean	9.9%	15%	0.0%
Std Dev	13.1%	20%	0.0%
Variance	0.01725488	25%	0.0%
Skewness	1.08917526	30%	0.0%
Kurtosis	3.573969709	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	36.0%	60%	20.0%
Right P	95%	65%	20.0%
Diff X	36.0%	70%	20.0%
Diff P	90%	75%	20.0%
#Errors	0	80%	20.0%
Filter Min	Off	85%	20.0%
Filter Max	Off	90%	20.0%
#Filtered	0	95%	36.0%



Regression and Rank Information for ASCM SURVI

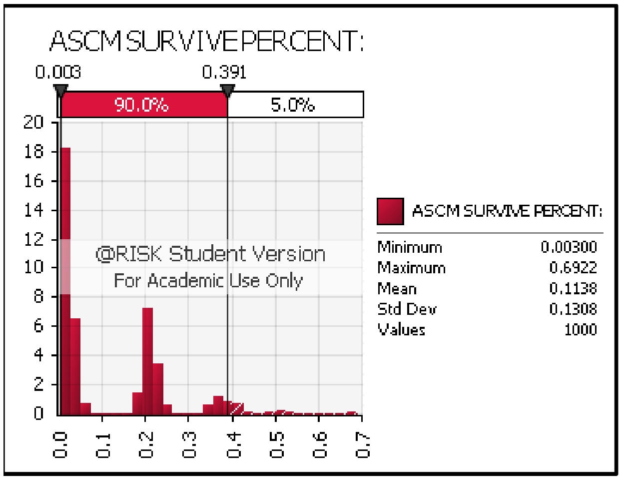
Rank	Name	Regr	Corr
1	KILL/HIT-0	-0.709	-0.668
2	ENGAGE-0	-0.704	-0.682
3	DETECTION-0	-0.121	-0.131
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

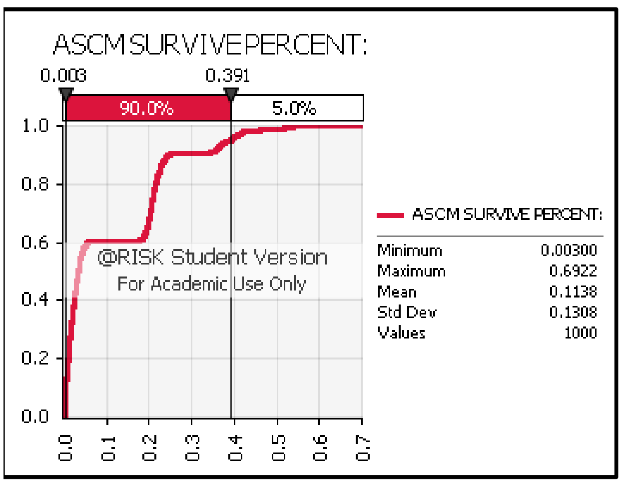
Table 54. @Risk results for SARDINE.

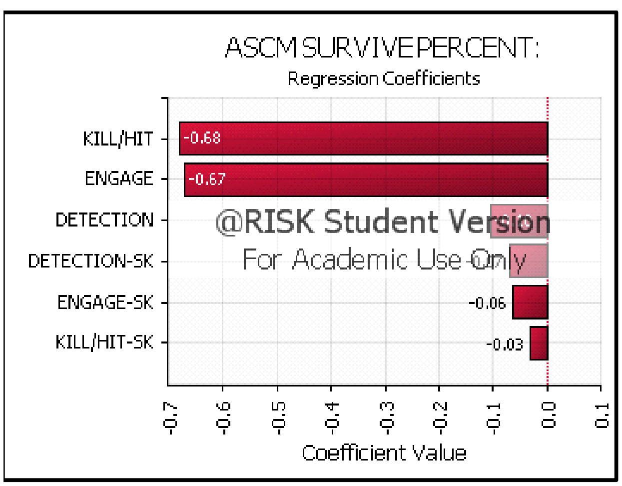
@RISK Output Report for SARDINE with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 1:21:37 PM

N = 5, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 13:21:28
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	60772496

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	69.2%	10%	0.4%
Mean	11.4%	15%	0.8%
Std Dev	13.1%	20%	1.1%
Variance	0.017107899	25%	1.3%
Skewness	1.163582396	30%	1.6%
Kurtosis	3.738940441	35%	2.0%
Median	3.4%	40%	2.4%
Mode	0.3%	45%	2.8%
Left X	0.3%	50%	3.4%
Left P	5%	55%	4.0%
Right X	39.1%	60%	5.5%
Right P	95%	65%	19.5%
Diff X	38.8%	70%	20.3%
Diff P	90%	75%	20.9%
#Errors	0	80%	21.5%
Filter Min	Off	85%	22.6%
Filter Max	Off	90%	24.5%
#Filtered	0	95%	39.1%

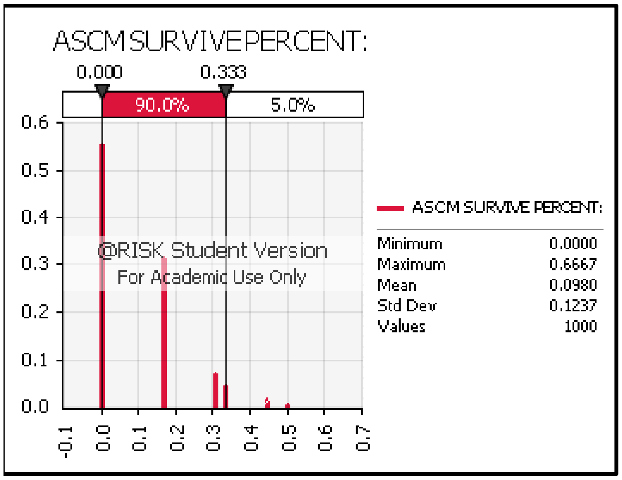
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.681	-0.613
2	ENGAGE	-0.671	-0.601
3	DETECTION	-0.104	-0.109
4	DETECTION-SK	-0.069	-0.330
5	ENGAGE-SK	-0.062	-0.206
6	KILL/HIT-SK	-0.030	-0.124
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

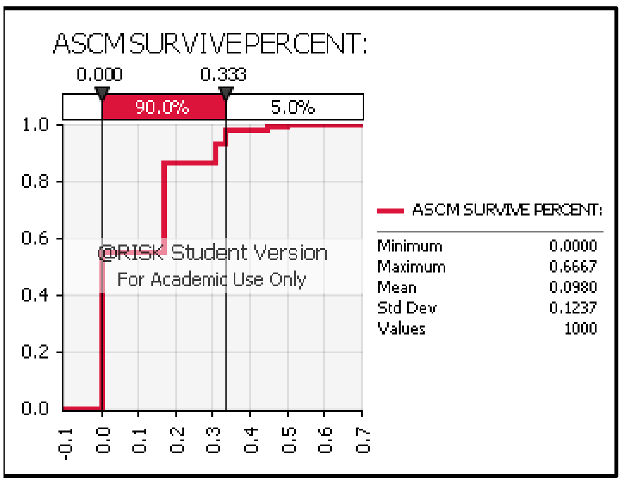
Table 55. @Risk results for SARDINE with soft kill.

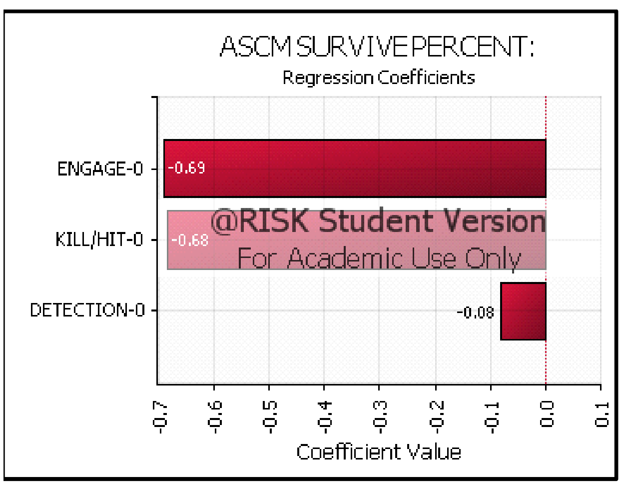
@RISK Output Report for STYX:

Performed By: Roy Smith
Date: Friday, April 02, 2010 2:21:53 PM

N = 6, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 14:21:34
Simulation Duration	00:00:17
Random # Generator	Mersenne Twister
Random Seed	1985319055

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	66.7%	10%	0.0%
Mean	9.8%	15%	0.0%
Std Dev	12.4%	20%	0.0%
Variance	0.015303235	25%	0.0%
Skewness	1.055002774	30%	0.0%
Kurtosis	3.520932653	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	33.3%	60%	16.7%
Right P	95%	65%	16.7%
Diff X	33.3%	70%	16.7%
Diff P	90%	75%	16.7%
#Errors	0	80%	16.7%
Filter Min	Off	85%	16.7%
Filter Max	Off	90%	30.6%
#Filtered	0	95%	33.3%

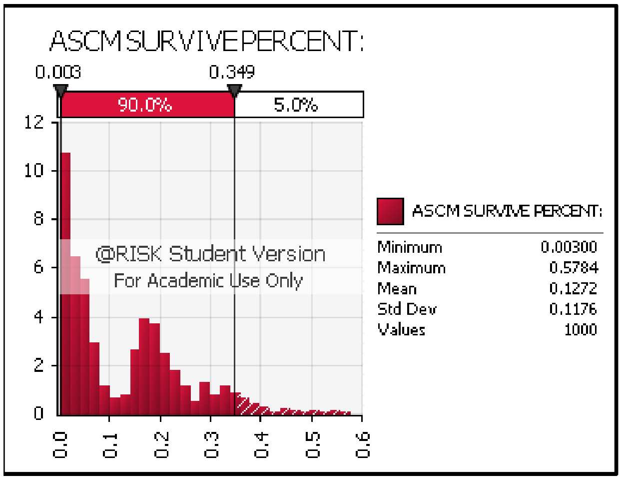
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE-0	-0.690	-0.708
2	KILL/HIT-0	-0.684	-0.705
3	DETECTION-0	-0.082	-0.063
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

Table 56. @Risk results for STYX.

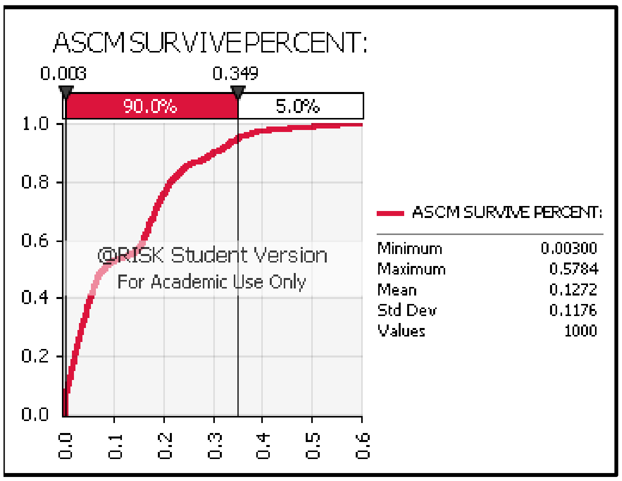
@RISK Output Report for STYX withSoft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 2:36:48 PM

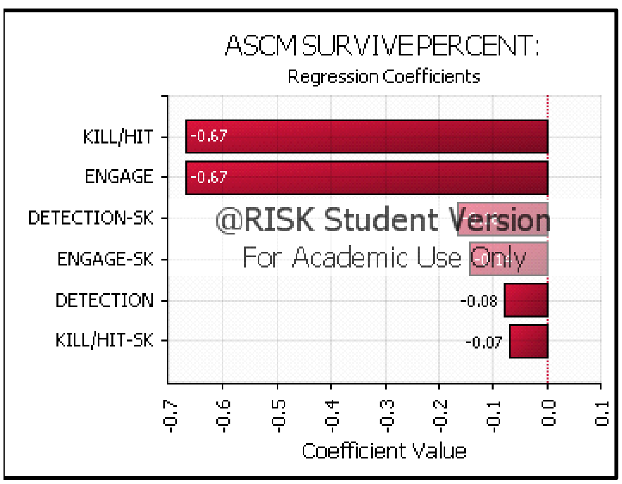
N = 6, Iterations = 1,000



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 14:36:40
Simulation Duration	00:00:06
Random # Generator	Mersenne Twister
Random Seed	1842262889



Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	57.8%	10%	0.7%
Mean	12.7%	15%	1.4%
Std Dev	11.8%	20%	2.1%
Variance	0.013840201	25%	2.8%
Skewness	0.997015293	30%	3.5%
Kurtosis	3.52740429	35%	4.4%
Median	7.8%	40%	5.2%
Mode	0.3%	45%	6.2%
Left X	0.3%	50%	7.8%
Left P	5%	55%	12.9%
Right X	34.9%	60%	15.9%
Right P	95%	65%	17.1%
Diff X	34.6%	70%	18.4%
Diff P	90%	75%	19.8%
#Errors	0	80%	21.5%
Filter Min	Off	85%	24.4%
Filter Max	Off	90%	30.0%
#Filtered	0	95%	34.9%



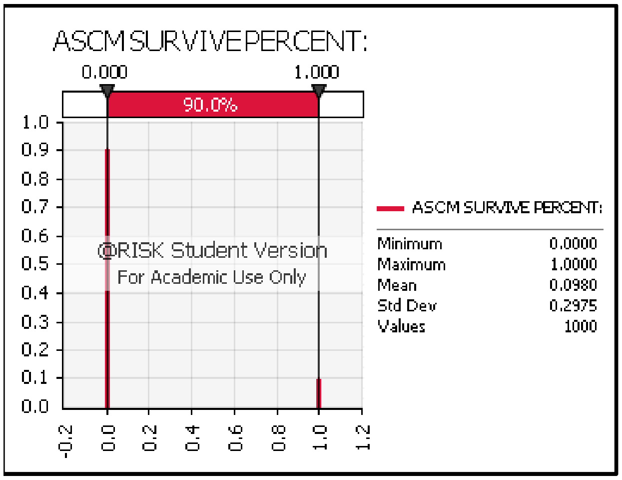
Regression and Rank Information for ASCM SURVI			
Rank	Name	Regr	Corr
1	KILL/HIT	-0.667	-0.621
2	ENGAGE	-0.667	-0.623
3	DETECTION-SK	-0.163	-0.253
4	ENGAGE-SK	-0.143	-0.210
5	DETECTION	-0.078	-0.054
6	KILL/HIT-SK	-0.070	-0.099
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

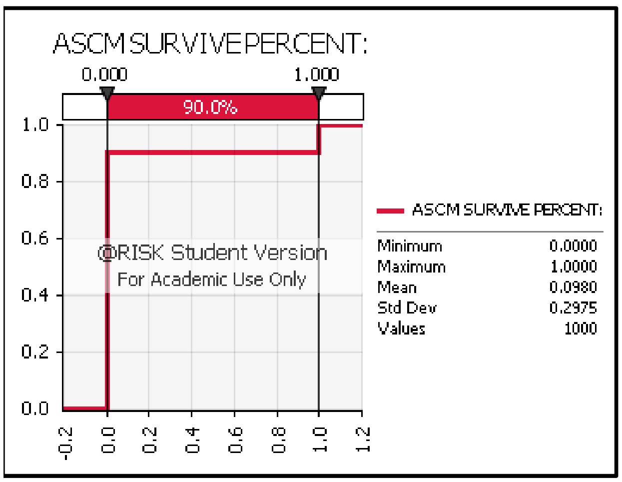
Table 57. @Risk results for STYX with soft kill.

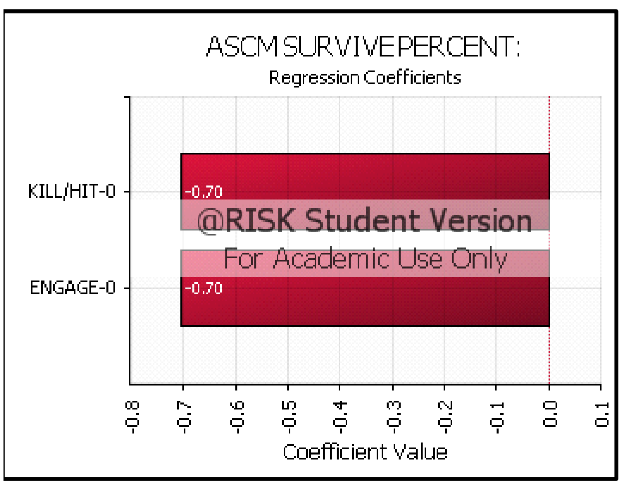
@RISK Output Report for SUNBURN 3M-80E:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 6:09:38 PM

N = 1, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 18:09:28
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1005300796

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	100.0%	10%	0.0%
Mean	9.8%	15%	0.0%
Std Dev	29.7%	20%	0.0%
Variance	0.088484484	25%	0.0%
Skewness	2.708269912	30%	0.0%
Kurtosis	8.345412761	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	100.0%	60%	0.0%
Right P	95%	65%	0.0%
Diff X	100.0%	70%	0.0%
Diff P	90%	75%	0.0%
#Errors	0	80%	0.0%
Filter Min	Off	85%	0.0%
Filter Max	Off	90%	0.0%
#Filtered	0	95%	100.0%

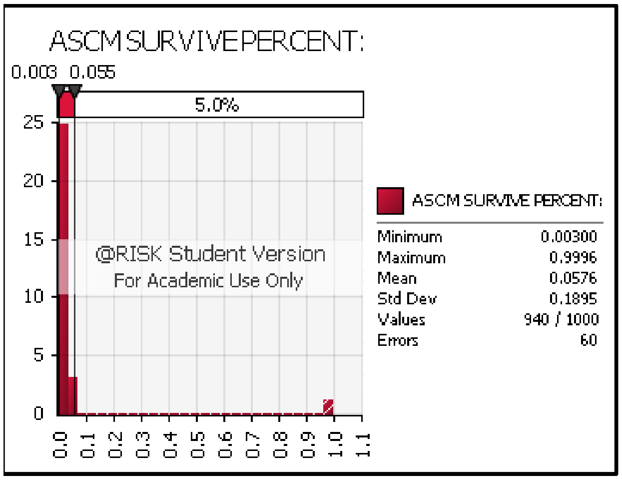
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.703	-0.696
2	ENGAGE-0	-0.703	-0.696
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

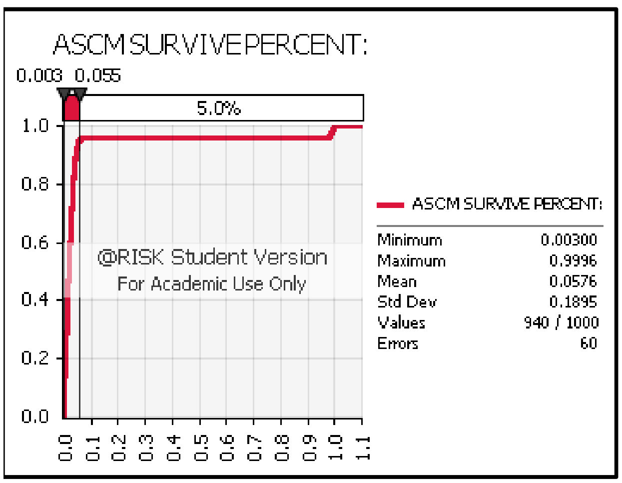
Table 58. @Risk results for SUNBURN 3M-80E.

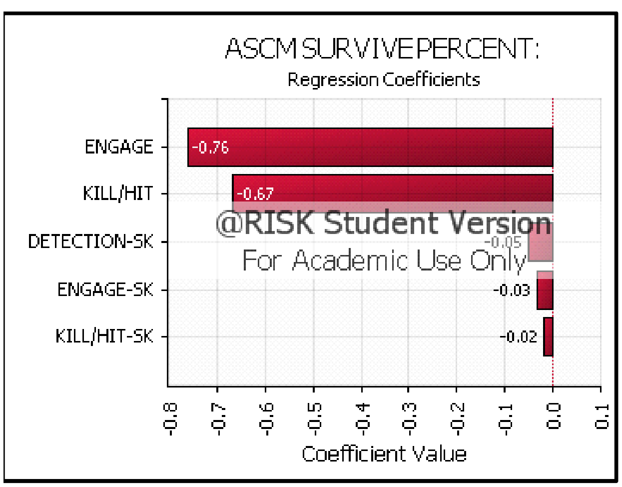
@RISK Output Report for SUNBURN 3M-80E with Soft Kill:

Performed By: Roy Smith

Date: Sunday, March 28, 2010 9:10:21 PM **N = 1, Iterations = 1,000**







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 21:10:12
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1863933933

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	100.0%	10%	0.3%
Mean	5.8%	15%	0.3%
Std Dev	18.9%	20%	0.6%
Variance	0.035904144	25%	0.8%
Skewness	4.706737098	30%	1.0%
Kurtosis	23.3280487	35%	1.2%
Median	1.7%	40%	1.4%
Mode	0.3%	45%	1.5%
Left X	0.3%	50%	1.7%
Left P	5%	55%	2.0%
Right X	5.5%	60%	2.2%
Right P	95%	65%	2.5%
Diff X	5.2%	70%	2.7%
Diff P	90%	75%	3.1%
#Errors	60	80%	3.4%
Filter Min	Off	85%	3.7%
Filter Max	Off	90%	4.2%
#Filtered	0	95%	5.5%

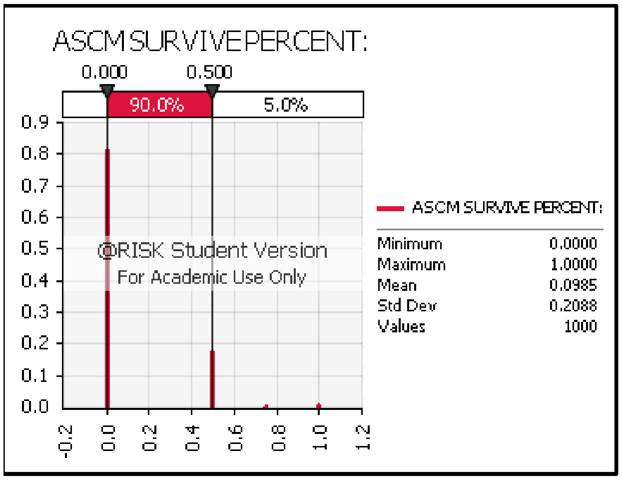
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	ENGAGE	-0.759	-0.249
2	KILL/HIT	-0.667	-0.223
3	DETECTION-SK	-0.051	-0.626
4	ENGAGE-SK	-0.033	-0.406
5	KILL/HIT-SK	-0.018	-0.206
6	DETECTION	0.000	0
7	DETECTION	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

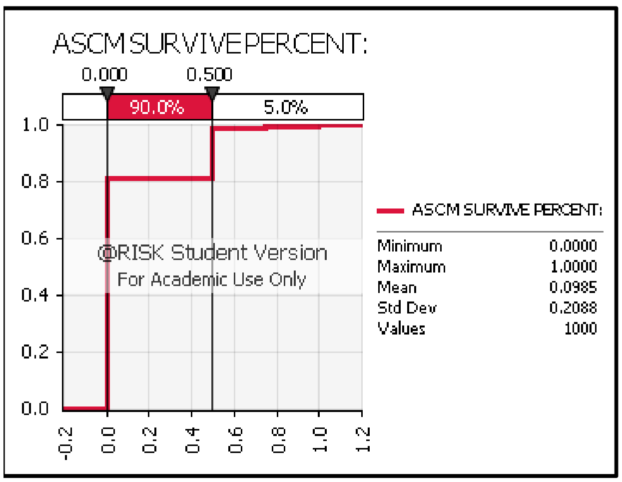
Table 59. @Risk results for SUNBURN 3M-80E with soft kill.

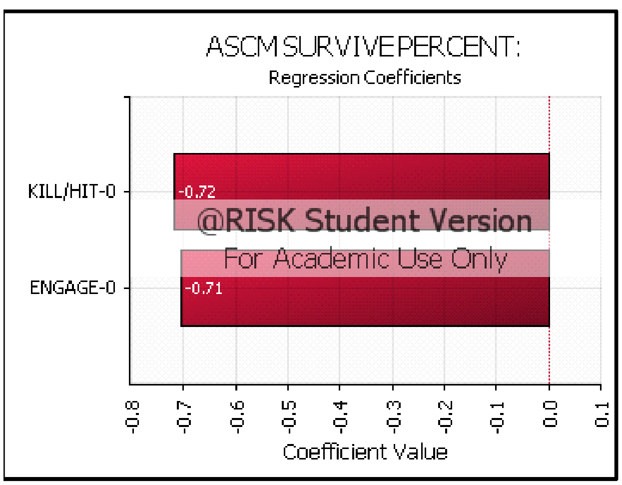
@RISK Output Report for SUNBURN Kh-41:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 9:20:17 PM

N = 2, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 21:20:08
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	746842976

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.0%	**5%**	0.0%
Maximum	100.0%	**10%**	0.0%
Mean	9.9%	**15%**	0.0%
Std Dev	20.9%	**20%**	0.0%
Variance	0.043591341	**25%**	0.0%
Skewness	1.810233511	**30%**	0.0%
Kurtosis	4.955478058	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	50.0%	**60%**	0.0%
Right P	95%	**65%**	0.0%
Diff X	50.0%	**70%**	0.0%
Diff P	90%	**75%**	0.0%
#Errors	0	**80%**	0.0%
Filter Min	Off	**85%**	50.0%
Filter Max	Off	**90%**	50.0%
#Filtered	0	**95%**	50.0%

Regression and Rank Information for ASCM SURVI

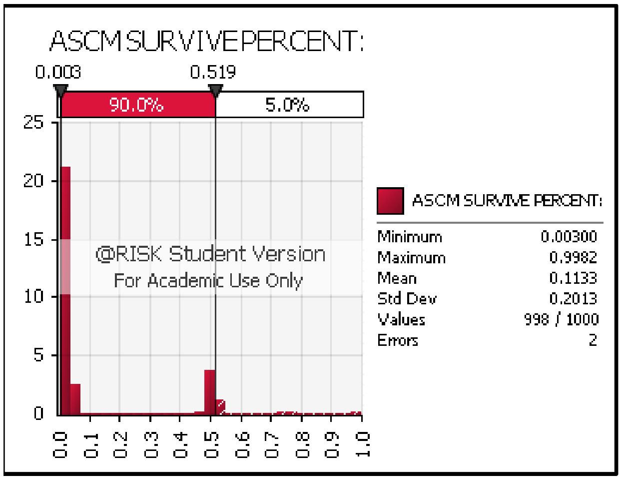
Rank	Name	Regr	Corr
1	KILL/HIT-0	-0.717	-0.691
2	ENGAGE-0	-0.706	-0.689
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

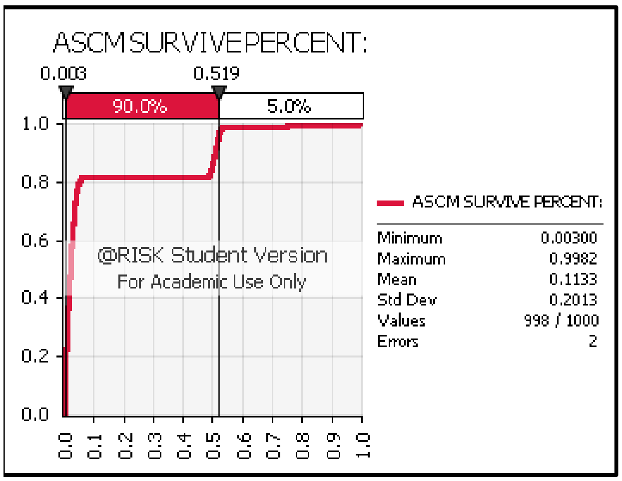
Table 60. @Risk results for SUNBURN Kh-41.

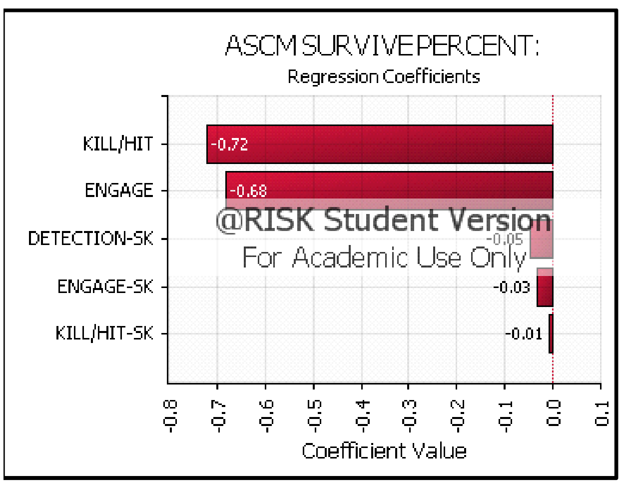
@RISK Output Report for ASCM SUNBURN Kh-41 with Soft Kill:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 9:15:25 PM

N = 2, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 21:15:15
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1174248174

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	99.8%	10%	0.3%
Mean	11.3%	15%	0.5%
Std Dev	20.1%	20%	0.7%
Variance	0.040537431	25%	1.0%
Skewness	1.773067124	30%	1.2%
Kurtosis	4.690061182	35%	1.4%
Median	2.2%	40%	1.6%
Mode	0.3%	45%	1.9%
Left X	0.3%	50%	2.2%
Left P	5%	55%	2.5%
Right X	51.9%	60%	2.7%
Right P	95%	65%	3.1%
Diff X	51.6%	70%	3.5%
Diff P	90%	75%	4.0%
#Errors	2	80%	5.0%
Filter Min	Off	85%	49.6%
Filter Max	Off	90%	50.8%
#Filtered	0	95%	51.9%

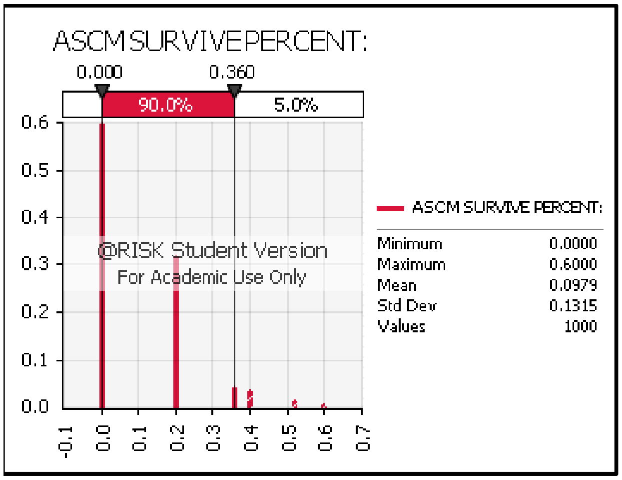
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.723	-0.473
2	ENGAGE	-0.682	-0.463
3	DETECTION-SK	-0.046	-0.478
4	ENGAGE-SK	-0.032	-0.372
5	KILL/HIT-SK	-0.008	-0.160
6	DETECTION	0.000	0
7	DETECTION	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

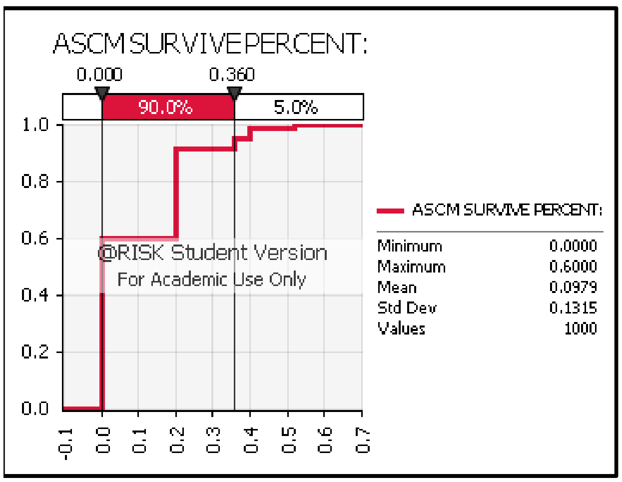
Table 61. @Risk results for SUNBURN Kh-41 with soft kill.

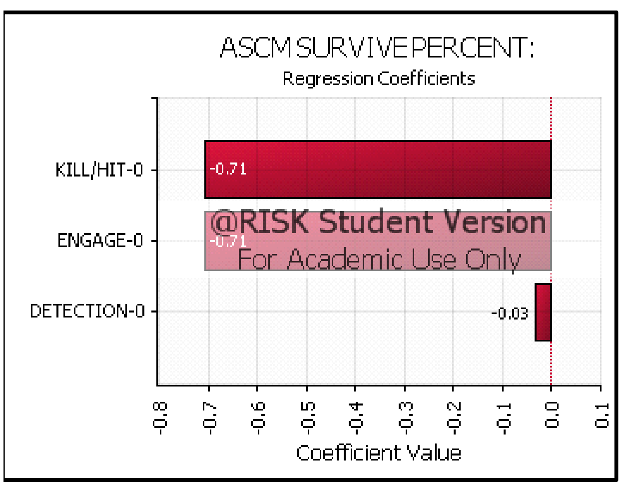
@RISK Output Report for SWITCHBLADE:

Performed By: Roy Smith
Date: Friday, April 02, 2010 2:52:29 PM

N = 5, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 14:52:20
Simulation Duration	00:00:07
Random # Generator	Mersenne Twister
Random Seed	438843005

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.0%	5%	0.0%
Maximum	60.0%	10%	0.0%
Mean	9.8%	15%	0.0%
Std Dev	13.2%	20%	0.0%
Variance	0.017296002	25%	0.0%
Skewness	1.110929065	30%	0.0%
Kurtosis	3.519591575	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	36.0%	60%	20.0%
Right P	95%	65%	20.0%
Diff X	36.0%	70%	20.0%
Diff P	90%	75%	20.0%
#Errors	0	80%	20.0%
Filter Min	Off	85%	20.0%
Filter Max	Off	90%	20.0%
#Filtered	0	95%	36.0%

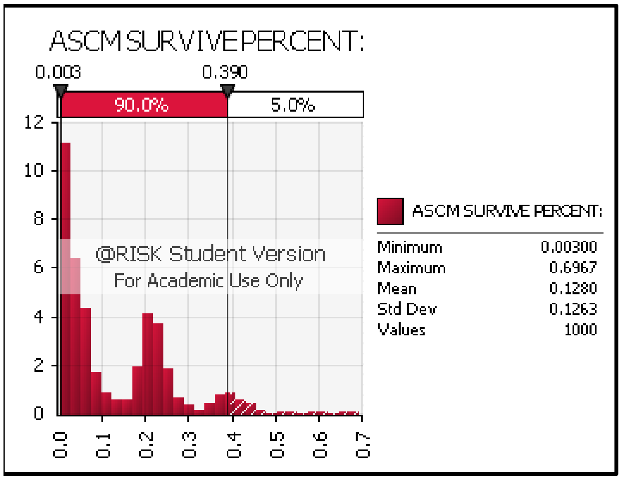
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT-0	-0.707	-0.687
2	ENGAGE-0	-0.705	-0.684
3	DETECTION-0	-0.033	-0.062
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

Table 62. @Risk results for SWITCHBLADE.

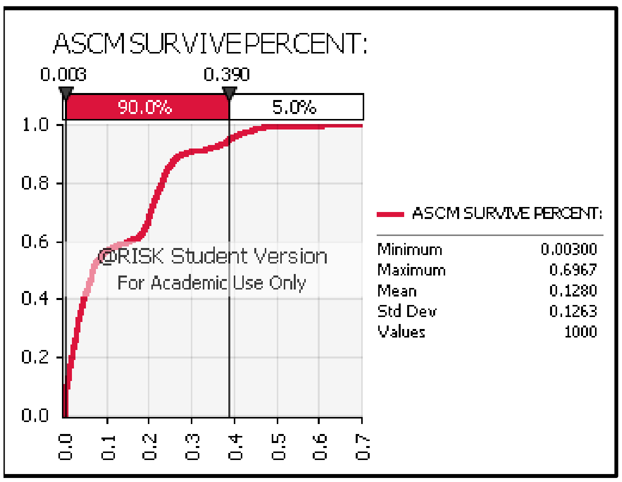
@RISK Output Report for SWITCHBLADE with Soft Kill:

Performed By: Roy Smith
Date: Friday, April 02, 2010 2:43:15 PM

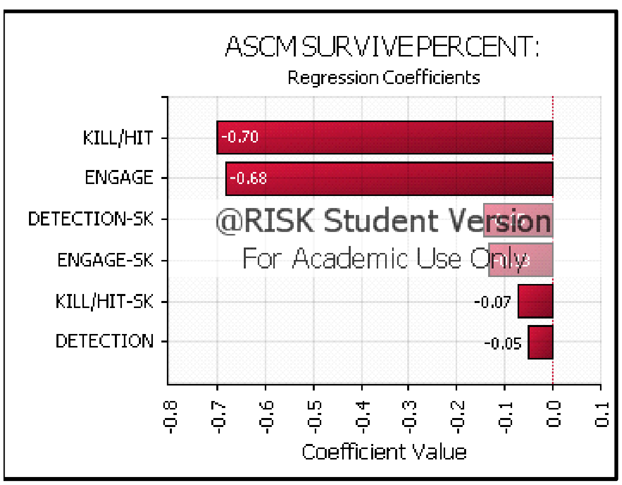
N = 5, Iterations =1,000



Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	4/2/10 14:42:55
Simulation Duration	00:00:18
Random # Generator	Mersenne Twister
Random Seed	449525148



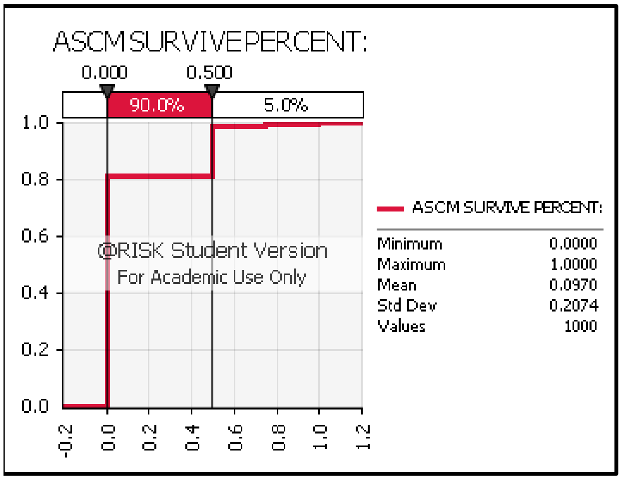
Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	69.7%	10%	0.5%
Mean	12.8%	15%	1.2%
Std Dev	12.6%	20%	1.8%
Variance	0.015963894	25%	2.4%
Skewness	1.087512177	30%	3.1%
Kurtosis	3.794972463	35%	3.7%
Median	6.7%	40%	4.6%
Mode	0.3%	45%	5.8%
Left X	0.3%	50%	6.7%
Left P	5%	55%	8.7%
Right X	39.0%	60%	15.2%
Right P	95%	65%	19.1%
Diff X	38.7%	70%	20.3%
Diff P	90%	75%	21.6%
#Errors	0	80%	23.0%
Filter Min	Off	85%	24.4%
Filter Max	Off	90%	27.4%
#Filtered	0	95%	39.0%



Regression and Rank Information for ASCM SURVI			
Rank	Name	Regr	Corr
1	KILL/HIT	-0.699	-0.611
2	ENGAGE	-0.681	-0.577
3	DETECTION-SK	-0.145	-0.271
4	ENGAGE-SK	-0.133	-0.208
5	KILL/HIT-SK	-0.072	-0.087
6	DETECTION	-0.050	-0.037
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

Table 63. @Risk results for SSWITCHBLADE with soft kill.

Minimum	0.0%	5%	0.0%
Maximum	100.0%	10%	0.0%
Mean	9.7%	15%	0.0%
Std Dev	20.7%	20%	0.0%
Variance	0.043009009	25%	0.0%
Skewness	1.819235279	30%	0.0%
Kurtosis	4.923506661	35%	0.0%
Median	0.0%	40%	0.0%
Mode	0.0%	45%	0.0%
Left X	0.0%	50%	0.0%
Left P	5%	55%	0.0%
Right X	50.0%	60%	0.0%
Right P	95%	65%	0.0%
Diff X	50.0%	70%	0.0%
Diff P	90%	75%	0.0%
#Errors	0	80%	0.0%
Filter Min	Off	85%	50.0%
Filter Max	Off	90%	50.0%
#Filtered	0	95%	50.0%



Regression and Rank Information for ASCM SURVI

Rank	Name	Regr	Corr
1	ENGAGE-0	-0.704	-0.698
2	KILL/HIT-0	-0.701	-0.694
3	DETECTION-0	0.000	0
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

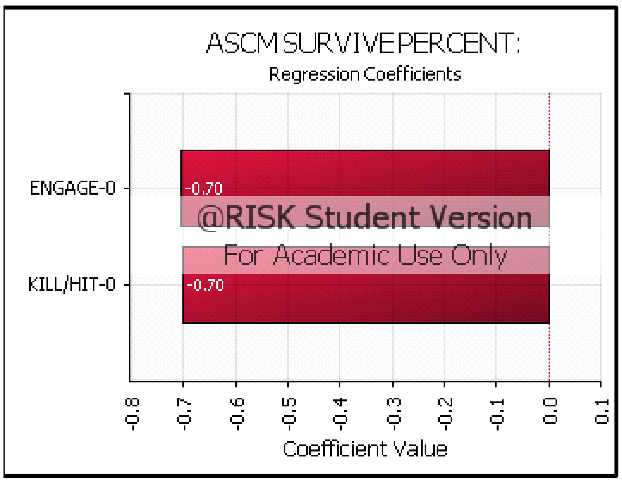
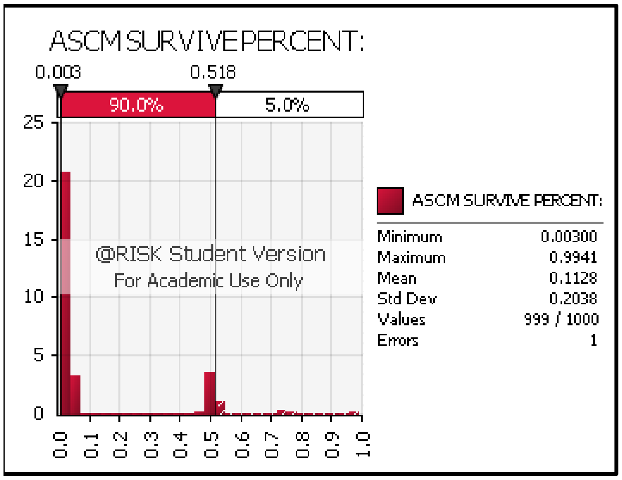


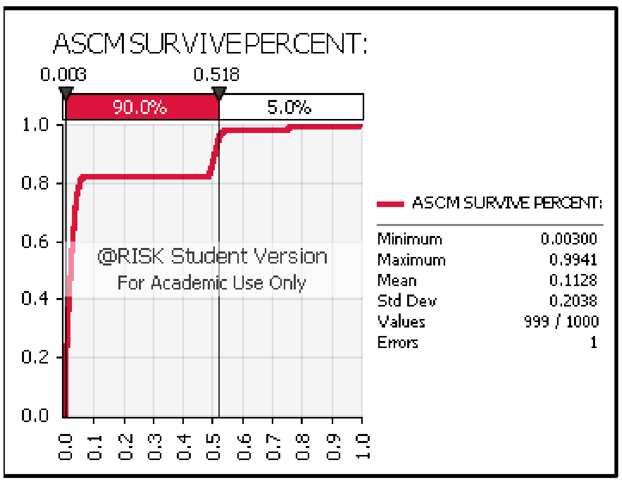
Table 64. @Risk results for BRAHMOS.

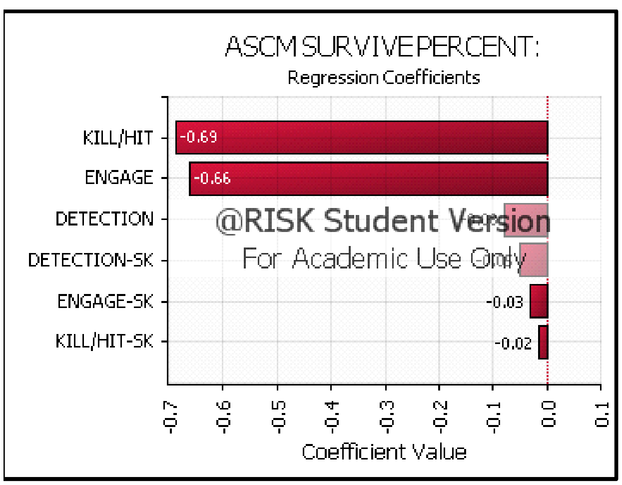
@RISK Output Report for BRAHMOS with Soft Kill:

Performed By: Roy Smith
Date: Sunday, March 28, 2010 9:28:05 PM

N = 2, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/28/10 21:27:46
Simulation Duration	00:00:18
Random # Generator	Mersenne Twister
Random Seed	1745539091

Summary Statistics for ASCM SURVIVE PERCENT:			
Statistics		**Percentile**	
Minimum	0.3%	5%	0.3%
Maximum	99.4%	10%	0.3%
Mean	11.3%	15%	0.4%
Std Dev	20.4%	20%	0.7%
Variance	0.041537364	25%	0.9%
Skewness	1.865956565	30%	1.1%
Kurtosis	5.138174772	35%	1.4%
Median	2.2%	40%	1.6%
Mode	0.3%	45%	1.9%
Left X	0.3%	50%	2.2%
Left P	5%	55%	2.5%
Right X	51.8%	60%	2.8%
Right P	95%	65%	3.2%
Diff X	51.5%	70%	3.6%
Diff P	90%	75%	4.1%
#Errors	1	80%	5.3%
Filter Min	Off	85%	49.4%
Filter Max	Off	90%	50.7%
#Filtered	0	95%	51.8%

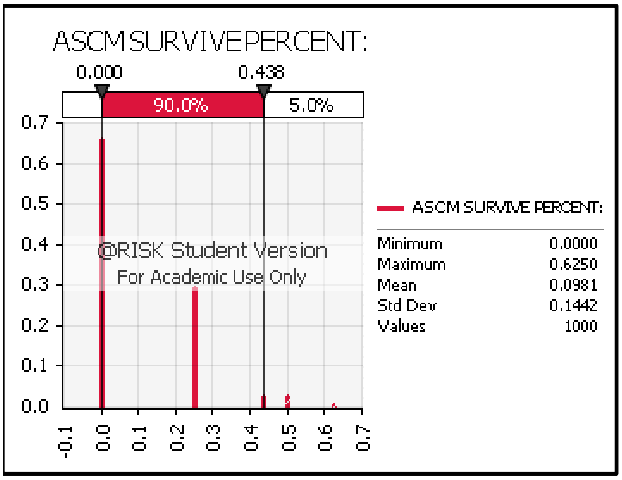
Regression and Rank Information for ASCM SURVI			
Rank	**Name**	**Regr**	**Corr**
1	KILL/HIT	-0.687	-0.480
2	ENGAGE	-0.663	-0.470
3	DETECTION	-0.077	-0.053
4	DETECTION-SK	-0.049	-0.453
5	ENGAGE-SK	-0.030	-0.346
6	KILL/HIT-SK	-0.016	-0.207
7	DETECTION-0	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

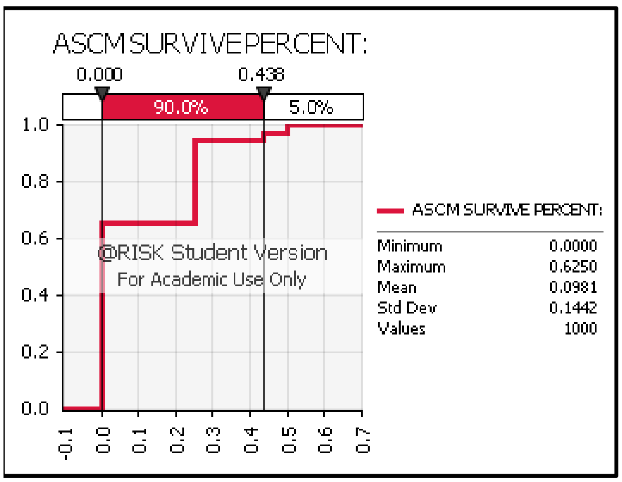
Table 65. @Risk results for BRAHMOS with soft kill.

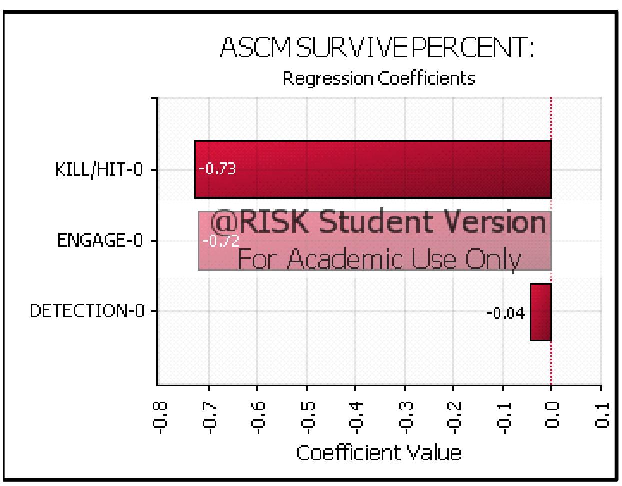
@RISK Output Report for RBS-15:

Performed By: Roy Smith

Date: Wednesday, March 31, 2010 8:56:35 PM N = 4, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 20:56:25
Simulation Duration	00:00:09
Random # Generator	Mersenne Twister
Random Seed	1404706788

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.0%	**5%**	0.0%
Maximum	62.5%	**10%**	0.0%
Mean	9.8%	**15%**	0.0%
Std Dev	14.4%	**20%**	0.0%
Variance	0.020799076	**25%**	0.0%
Skewness	1.15096283	**30%**	0.0%
Kurtosis	3.323053469	**35%**	0.0%
Median	0.0%	**40%**	0.0%
Mode	0.0%	**45%**	0.0%
Left X	0.0%	**50%**	0.0%
Left P	5%	**55%**	0.0%
Right X	43.8%	**60%**	0.0%
Right P	95%	**65%**	0.0%
Diff X	43.8%	**70%**	25.0%
Diff P	90%	**75%**	25.0%
#Errors	0	**80%**	25.0%
Filter Min	Off	**85%**	25.0%
Filter Max	Off	**90%**	25.0%
#Filtered	0	**95%**	43.8%

Regression and Rank Information for ASCM SURVI

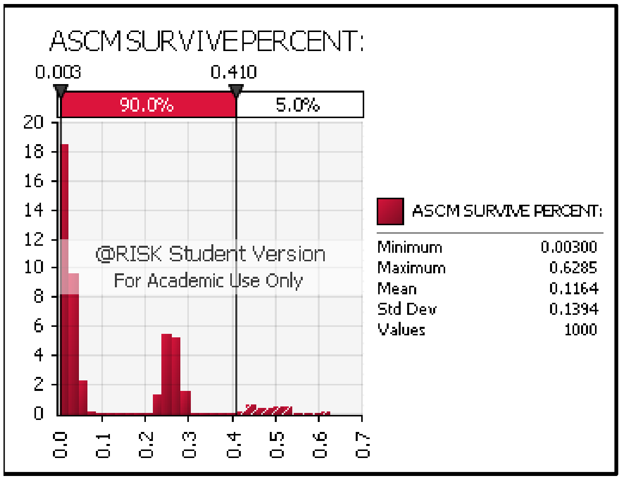
Rank	Name	Regr	Corr
1	KILL/HIT-0	-0.726	-0.679
2	ENGAGE-0	-0.719	-0.669
3	DETECTION-0	-0.043	-0.060
4	DETECTION-SK	0.000	0
5	DETECTION	0.000	0
6	ENGAGE-SK	0.000	0
7	ENGAGE	0.000	0
8	KILL/HIT-SK	0.000	0
9	KILL/HIT	0.000	0

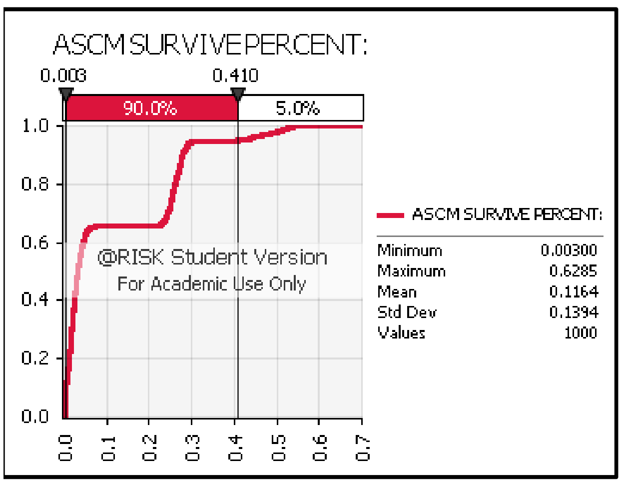
Table 66. @Risk results for RBS-15.

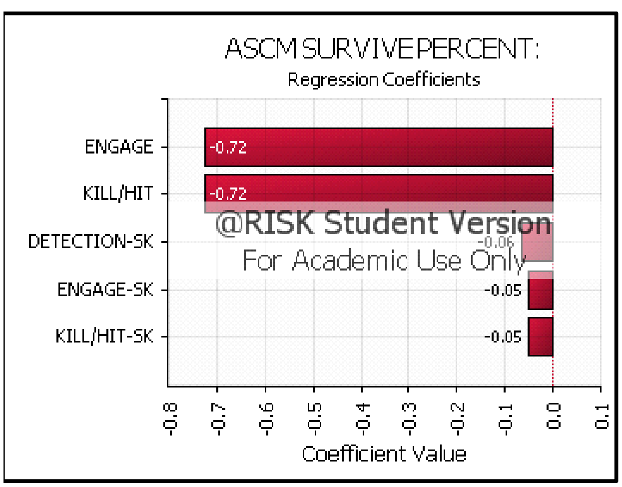
@RISK Output Report for RBS-15 with Soft Kill:

Performed By: Roy Smith
Date: Wednesday, March 31, 2010 9:16:57 PM

N = 4, Iterations = 1,000







Simulation Summary Information	
Workbook Name	ASCM_vs_SAM_Decision_Model.xlsm
Number of Simulations	1
Number of Iterations	1000
Number of Inputs	9
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	3/31/10 21:16:48
Simulation Duration	00:00:08
Random # Generator	Mersenne Twister
Random Seed	1189803295

Summary Statistics for ASCM SURVIVE PERCENT:

Statistics		Percentile	
Minimum	0.3%	5%	0.3%
Maximum	62.8%	10%	0.4%
Mean	11.6%	15%	0.9%
Std Dev	13.9%	20%	1.3%
Variance	0.01944453	25%	1.6%
Skewness	1.132175366	30%	1.8%
Kurtosis	3.316024125	35%	2.1%
Median	3.2%	40%	2.5%
Mode	0.3%	45%	2.8%
Left X	0.3%	50%	3.2%
Left P	5%	55%	3.8%
Right X	41.0%	60%	4.5%
Right P	95%	65%	6.4%
Diff X	40.7%	70%	24.4%
Diff P	90%	75%	25.4%
#Errors	0	80%	26.1%
Filter Min	Off	85%	27.1%
Filter Max	Off	90%	27.8%
#Filtered	0	95%	41.0%

Regression and Rank Information for ASCM SURVI

Rank	Name	Regr	Corr
1	ENGAGE	-0.725	-0.558
2	KILL/HIT	-0.724	-0.560
3	DETECTION-SK	-0.064	-0.330
4	ENGAGE-SK	-0.051	-0.251
5	KILL/HIT-SK	-0.050	-0.237
6	DETECTION	0.000	0
7	DETECTION	0.000	0
8	ENGAGE-0	0.000	0
9	KILL/HIT-0	0.000	0

Table 67. @Risk results for RBS-15 with soft kill.

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